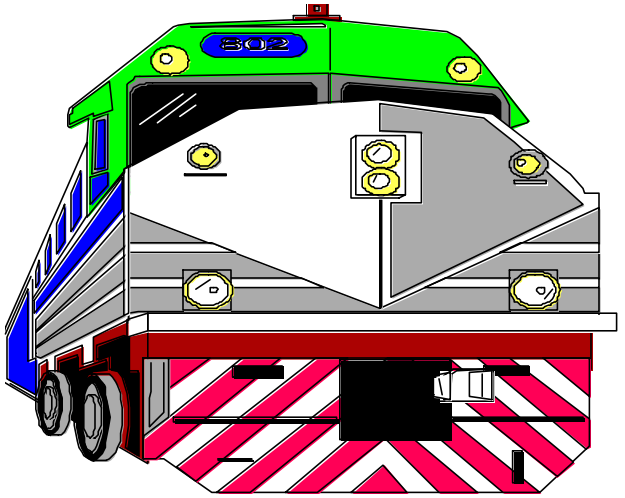
A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



ASCAP TUTORIAL

MARCH 4, 2003
Philadelphia

Center of Rail Safety-Critical Excellence
University of Virginia, School of Engineering and Applied Science
351 McCormick Road
Charlottesville, VA 22904-4743

Agenda (Morning)
March 4, 2003

…….A Day in the Safety of a CTC Train System

8:00 AM - 8:30 AM	INTRODUCTION	Dr. Ted C. Giras
8:30 AM - 9:45 AM	A DAY IN THE SAFETY OF A TRAIN SYSTEM	Mr. Marc E. Monfalcone
9:45 AM - 10:15 AM	BREAK	
10:15 AM - 12:00 AM	ASCAP SAFETY BEHAVIOR MODELS	Dr. Lori M. kaufman
12:00 AM - 1:15 PM	LUNCH	

Agenda (Afternoon)
March 4, 2003

…….A Day in the Safety of a CTC Train System

1:15 PM - 2:30PM	KNOWLEDGE-BASED BLACKBOARDS	Dr. Lori M. Kaufman
2:30 PM - 3:15 PM	CHOICE MODEL KNOWLEDGE-BASED BLACKBOARDS	Dr. Don E. Brown
3:15 PM - 4:15 PM	BREAK	
4:15 PM - 5:00 PM	ASCAP WEB-based PARALLEL PROCESSING CLUSTER COMPUTER	Dr. Ron D. Williams
5:00 PM	GROUP COMMENTS & DISCUSSION	

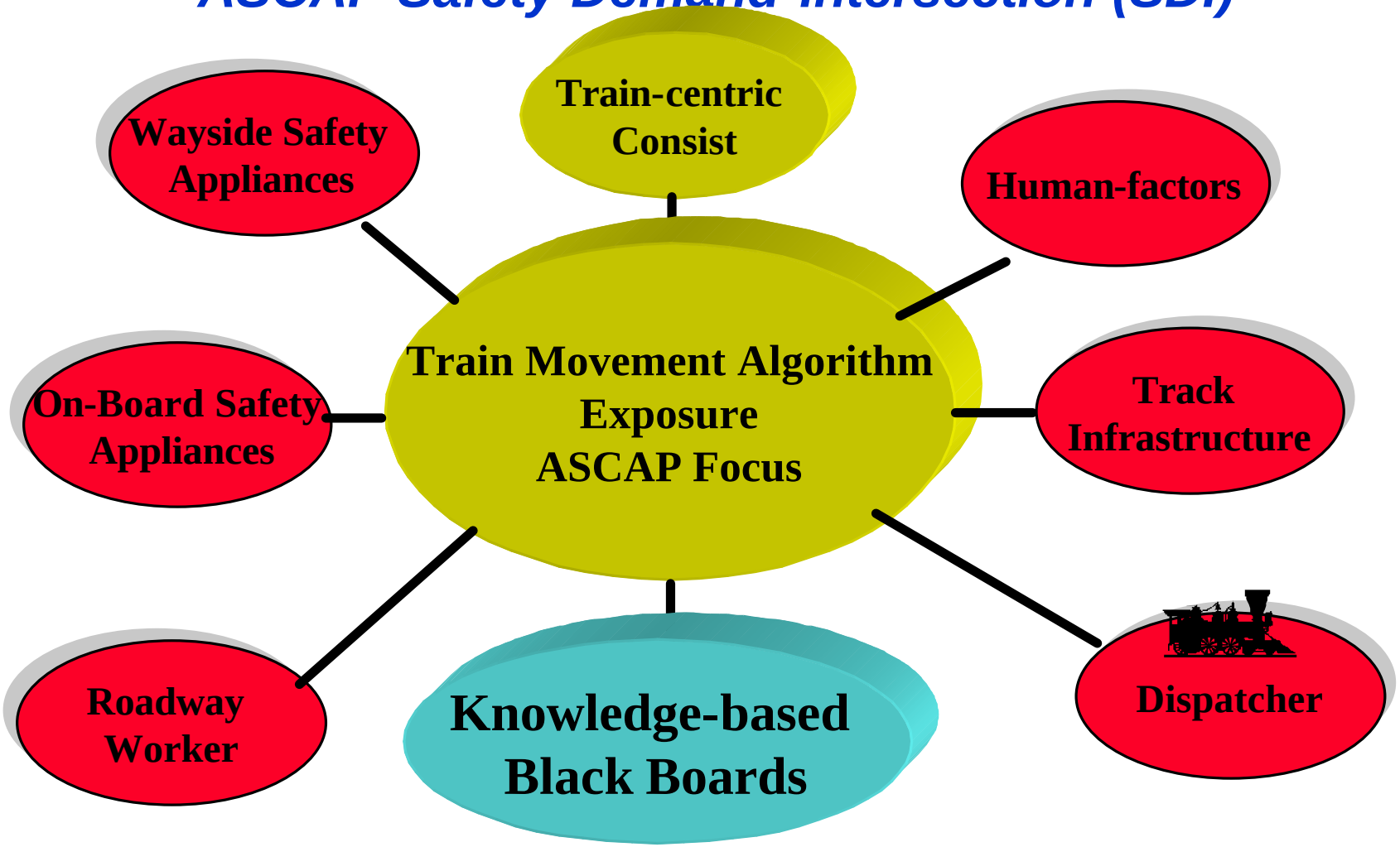
ASCAP RSAC Tutorial Purpose

- The purpose of the ASCAP RSAC Tutorial is:
  - Demonstrate to RSAC how ASCAP is Processor-based Rule Compliant with lessons learned from the IDOT Product Safety Plan (PSP) Work-in-Progress
  - Illustrate a ***Day in the Safety Demands of a Train System .*** Show how ASCAP provides a Design for Safety Assessment that supports the RSAC PSP
  - Describe the ASCAP Monte Carlo Simulation Safety Demand architecture:
    - Train Movement Model Determines Exposure
    - Safety Demand-Intersection (SDI) models,
    - Rule Book Knowledge Compliance – Non Compliance – Human-factors
    - Model (s) data base requirements: Objects & Agents
    - Design for Safety Product Safety Plan (PSP) information
  - Provide insight into the Safety Results Information available such as:
    - Risk (Societal Cost) versus Train Miles Traveled: Severity Model
    - Events Passed at Danger Logs - Safety State Histograms
    - Rule Book Compliance – Human-factors

Definitions

- ***Continuous Simulation:*** Describes physical behavior with dynamic equations that are solved numerically with respect to continuous time
- ***Discrete Event Simulation:*** Describes discrete events with the aid of algorithmic relationships that cause changes of state at discrete points
- ***Events Passed at Danger:*** Train has passed a discrete event whose state has created a potential danger for the Train as it travels along the track infrastructure
- ***Knowledge-based Black Boards:*** Operations rule book working memory that relates probabilistic object & agent behavior to train handling modalities controlled by an agenda scheduler that for ASCAP is a Monte Carlo process
- ***Monte Carlo:*** A heuristic probabilistic and sampling simulation method
- ***Safety Demand-Intersection Model:*** Safety state is determined at discrete spatial track intervals as a Train intersects with the appliance
- ***Stochastic:*** A random variable that has a probabilistic distribution usually with finite variance

ASCAP Safety Demand-Intersection (SDI)



Train-centric Movement Modalities

ASCAP Safety Assessment PSP Credible Evidences

- ***Decision Maker Info:*** Risk (Societal Cost) versus Train Miles Traveled
- ***Validation:*** Hazard-free String Chart Train Movements
- ***Verification:*** Non Hazard-free String Chart Train Movements
- ***Verification:*** Events Passed at Danger & Incident/Accident Severity Logs
- ***Verification:*** Safety Appliance Fail-Safe – Fail-Unsafe Coverage
- ***Verification:*** Operational, Fail-Safe and Fail-Unsafe Histograms
- ***Verification:*** Rule Book Compliance – Non Compliance
- ***Verification:*** Dispatcher, Train Crew and Roadway Worker Statistics

PSP Safety-Critical Evaluation

- PSP safety-critical evidences must be evaluated as collection of evidences with the objective:
  - Hazard-free validation of the Train Movement Exposure
  - Non hazard-free verification of Probabilistic & Continuous Behaviors
  - Verification of the Risk versus Train Miles Traveled evidences

ASCAP TEAM PRESENTATION

STRING CHART

TRAIN MOVMENT

EXPOSURE

Screen One

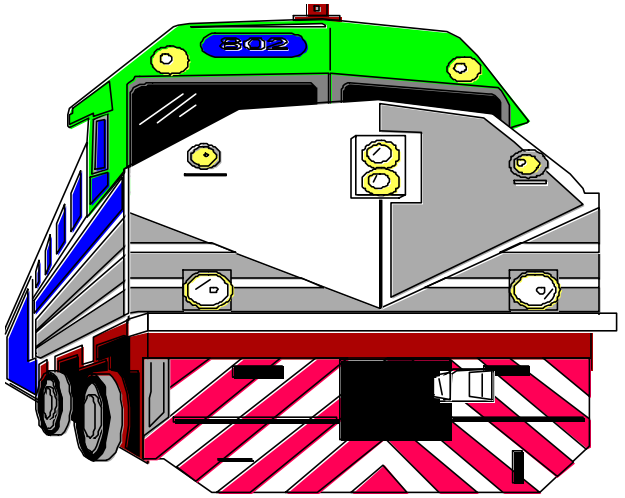
SAFETY DEMAND MODEL

INTERSECTION

BEHAVIOR

Screen Two

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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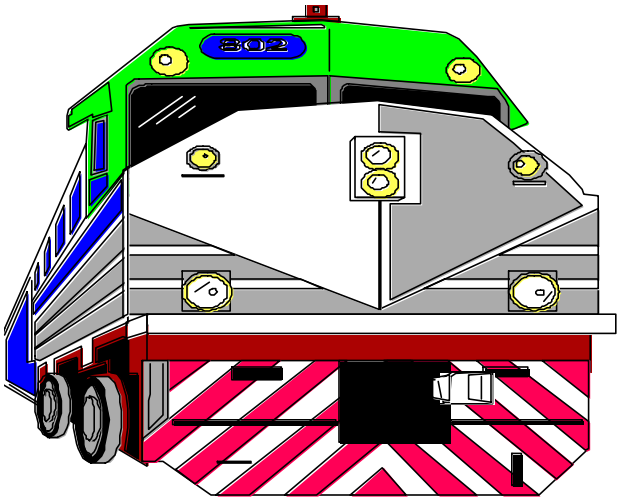

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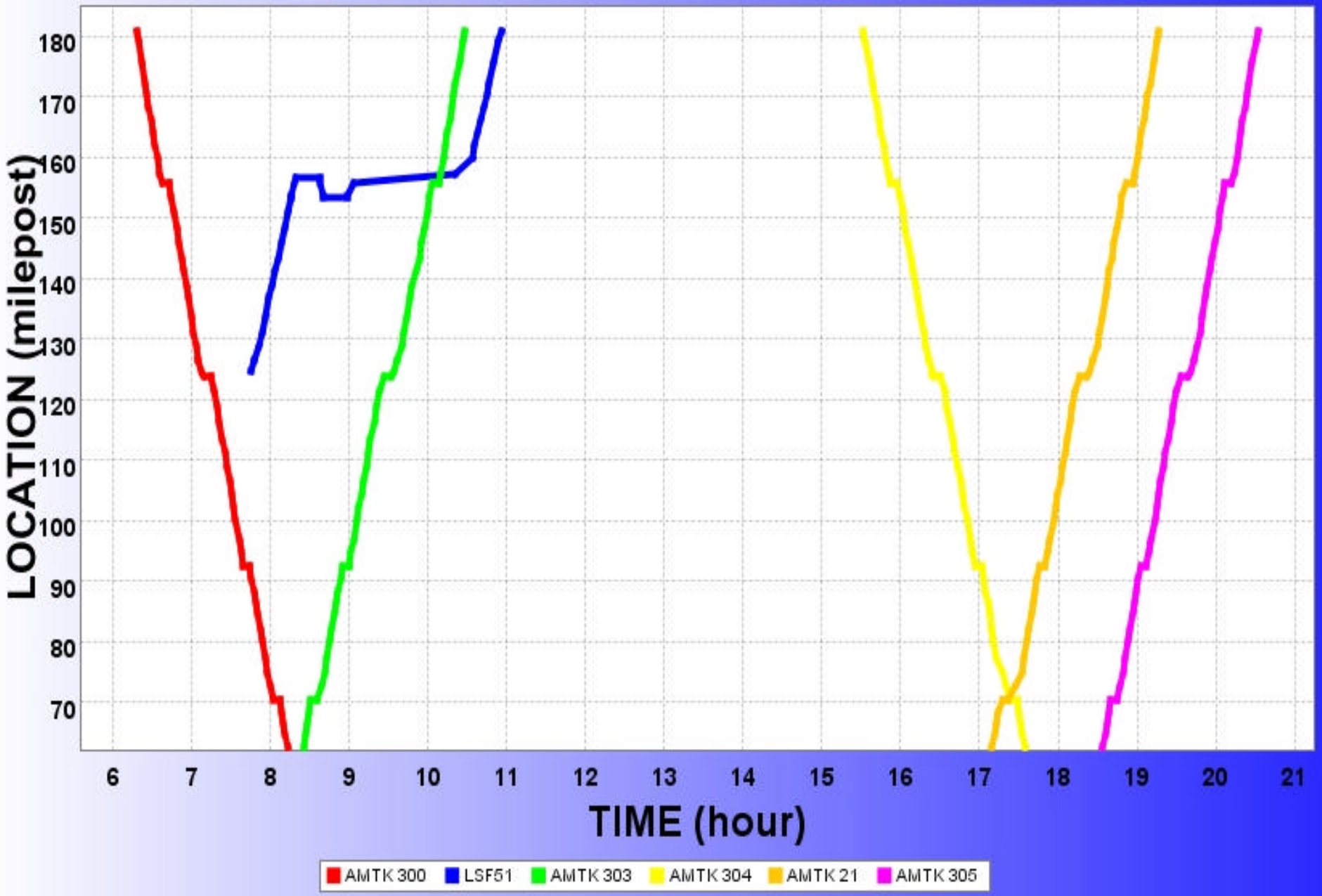
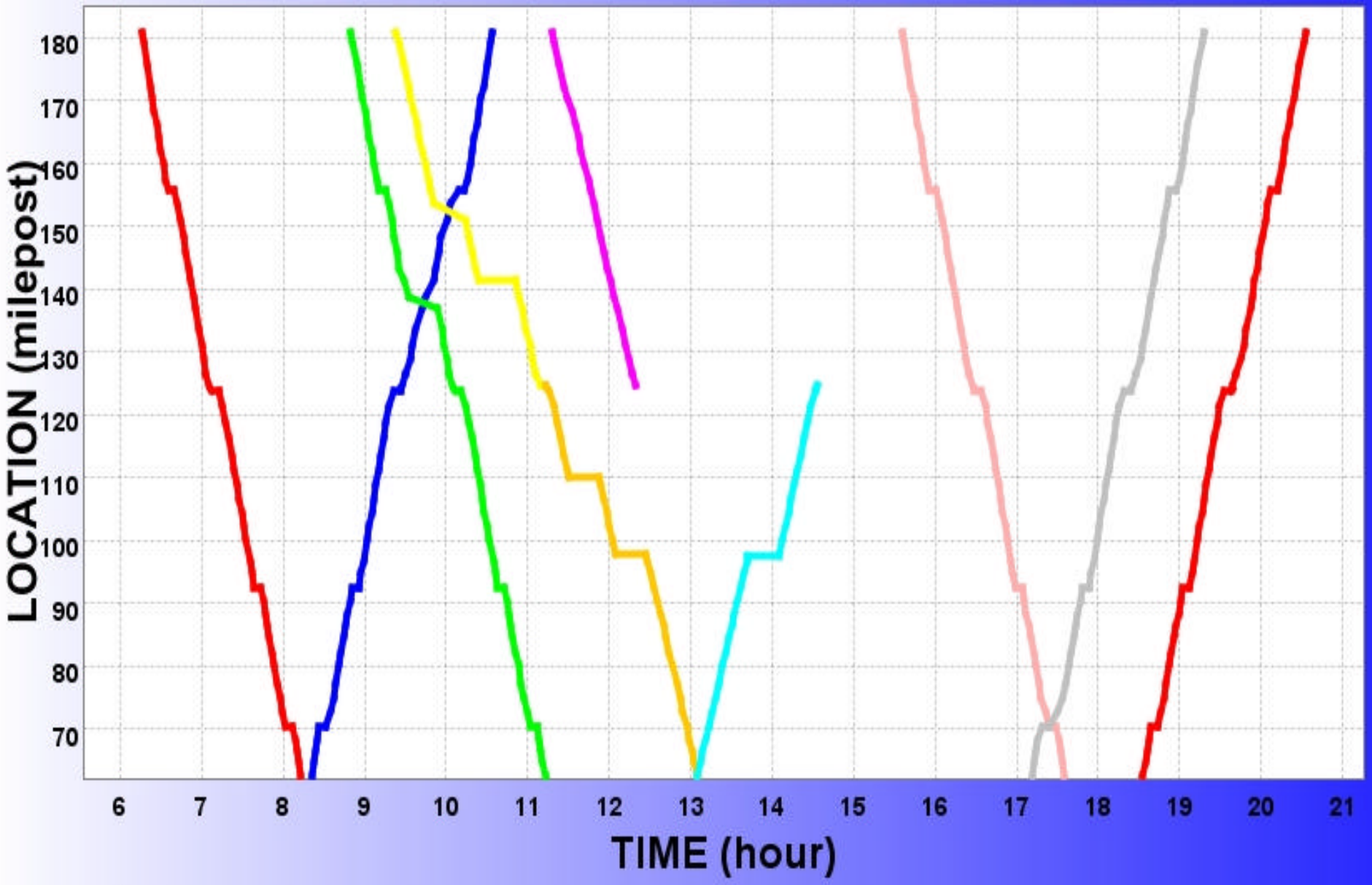
IDOT String Charts

- Illustrate a week in the life of the territory.
- Simulation output has been compared to actual traffic data from the corridor.
- Simulation has been peer reviewed by Labor.
  - An Amtrak Engineer, with twelve years of experience on the territory, was able to pick out trains by name, while looking at the string charts.
- Simulation output follows, one week of traffic.

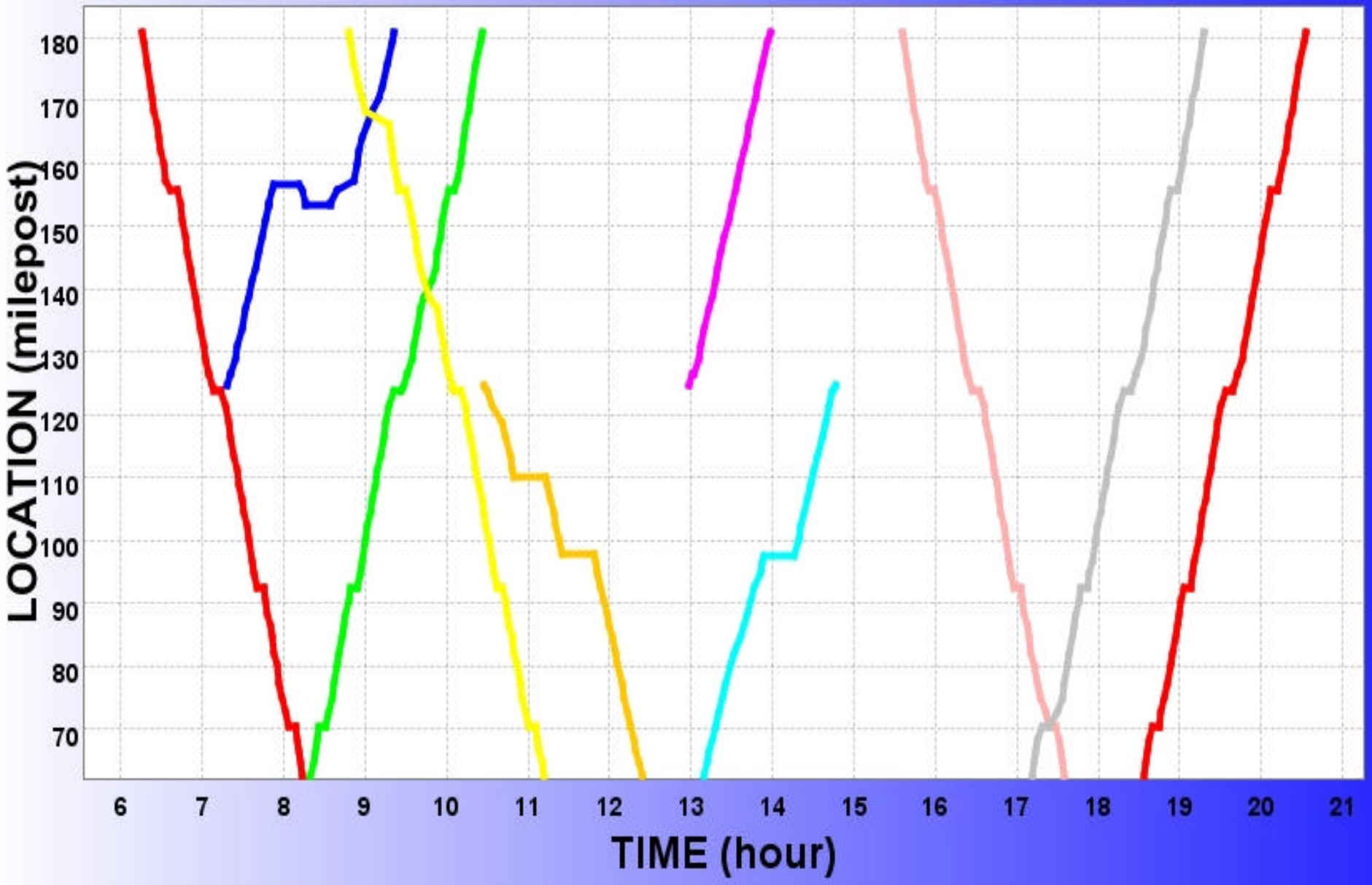
IDOT Chart for Sunday



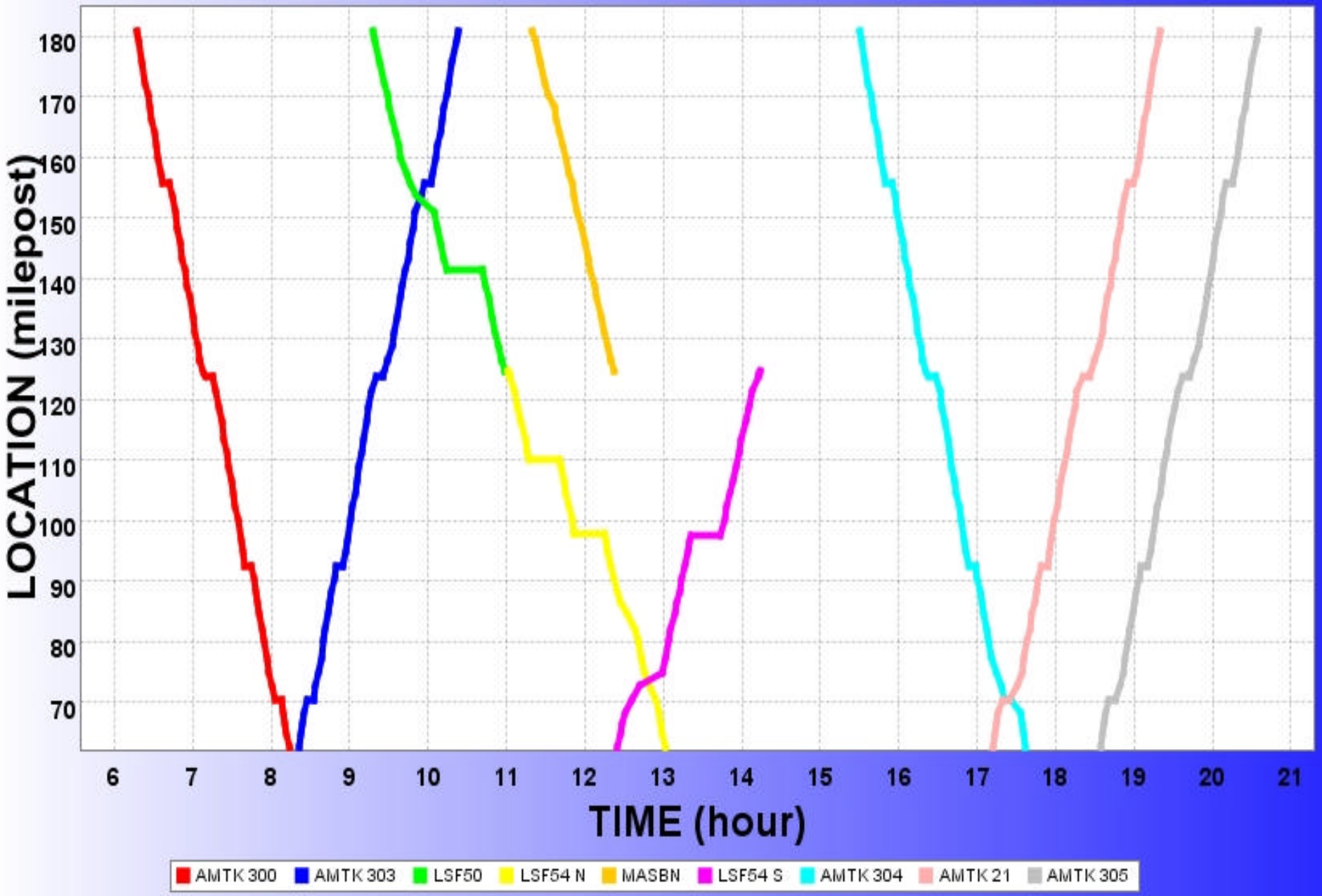
IDOT Chart for Monday



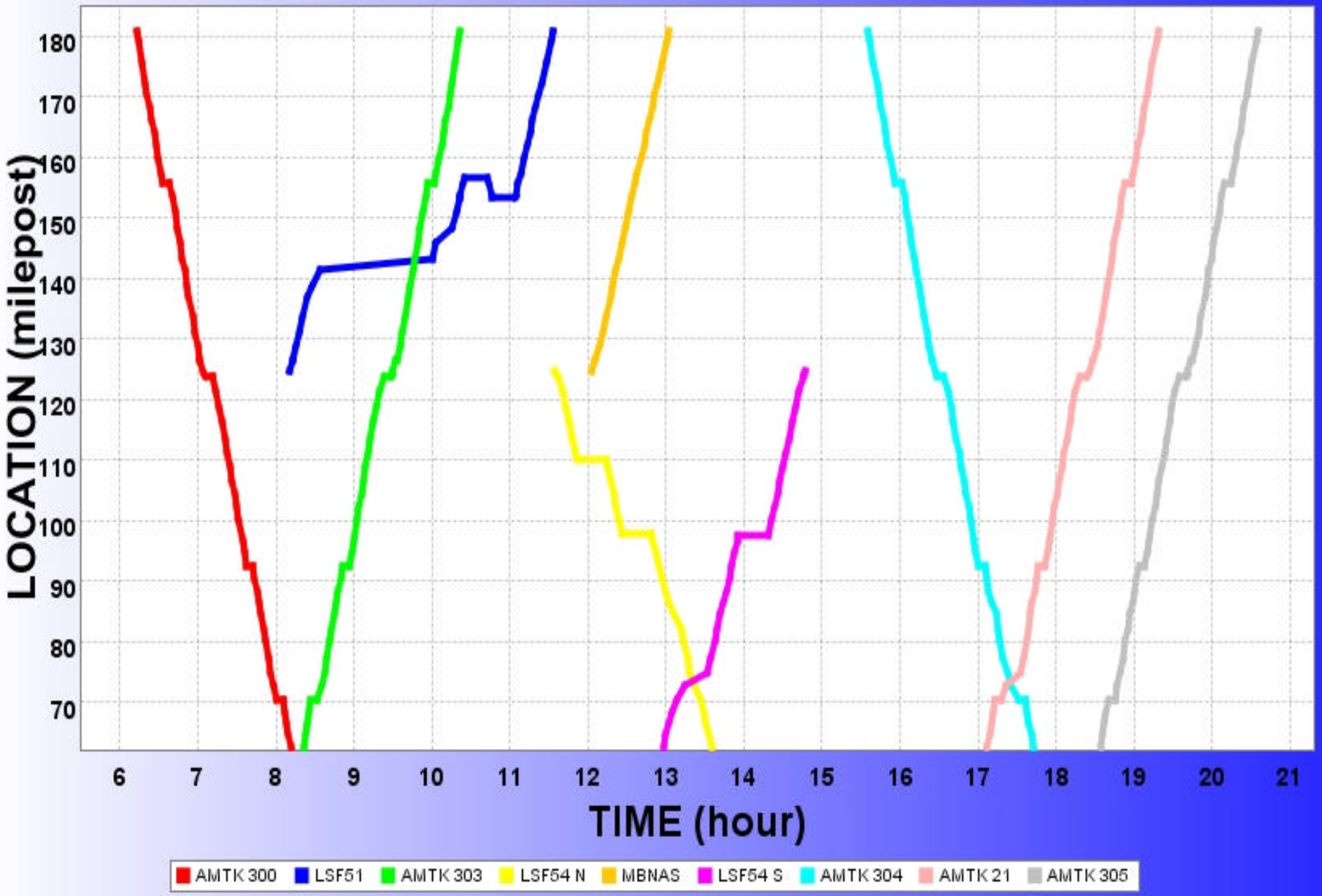
IDOT Chart for Tuesday



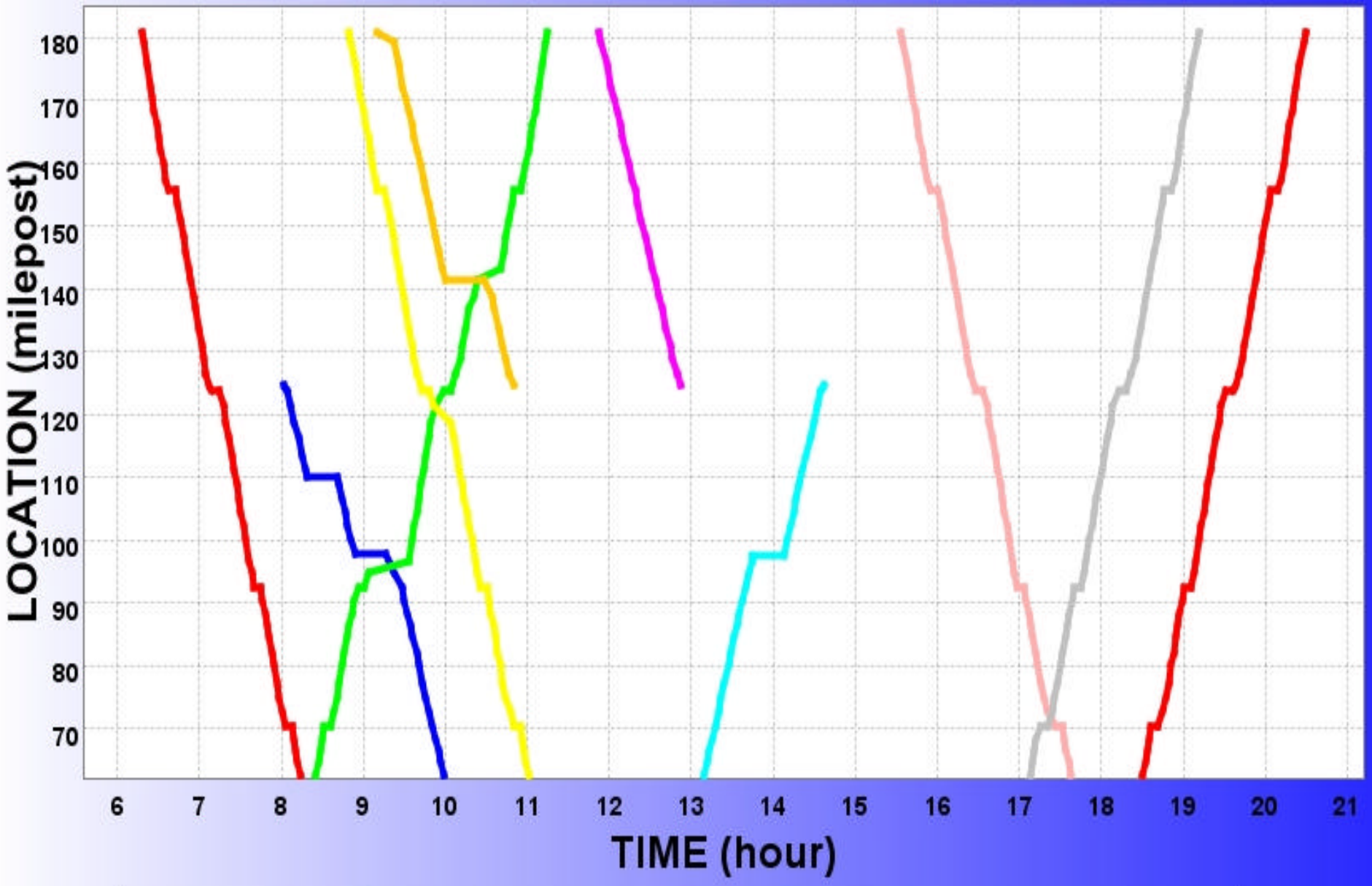
IDOT Chart for Wednesday



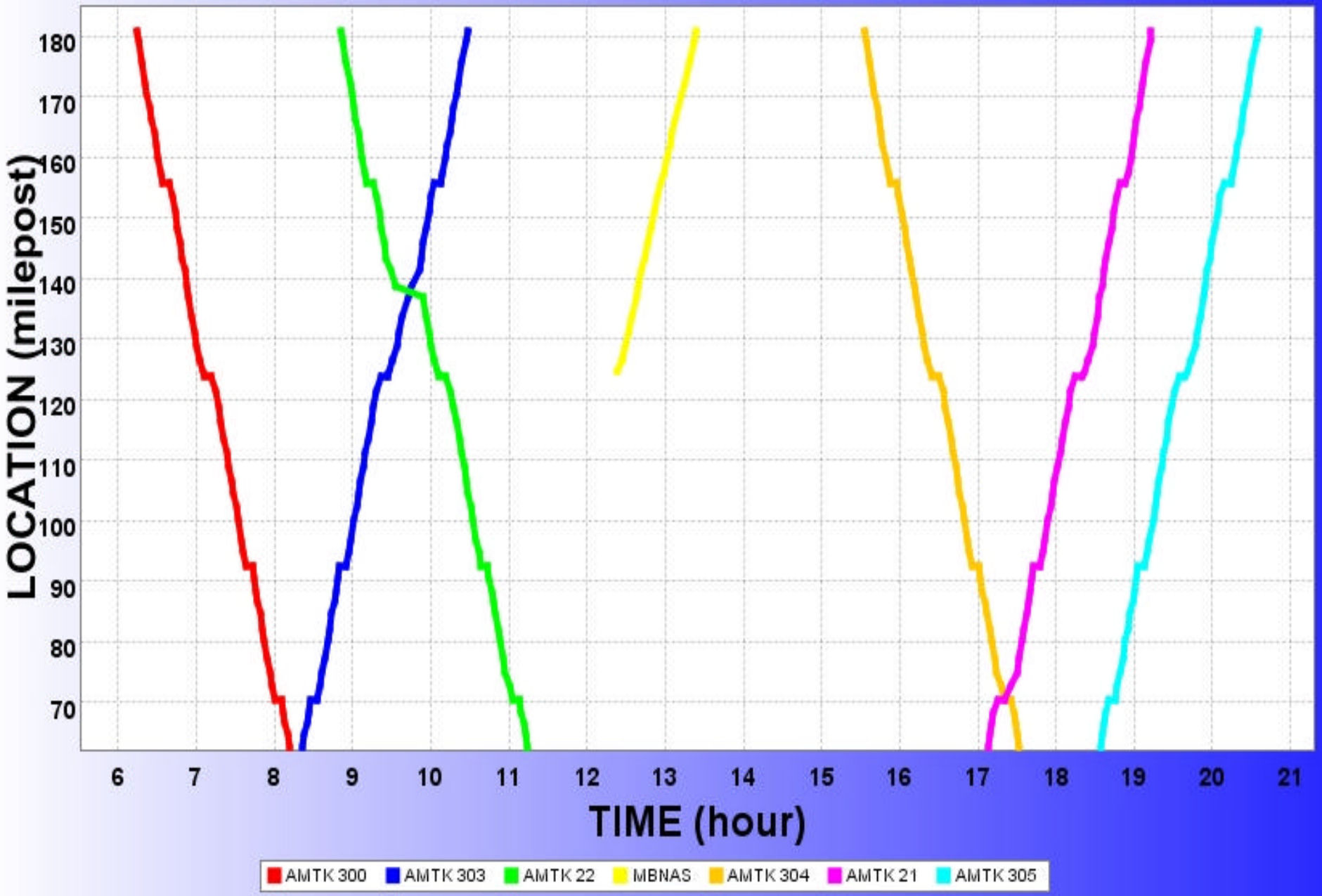
IDOT Chart for Thursday



IDOT Chart for Friday



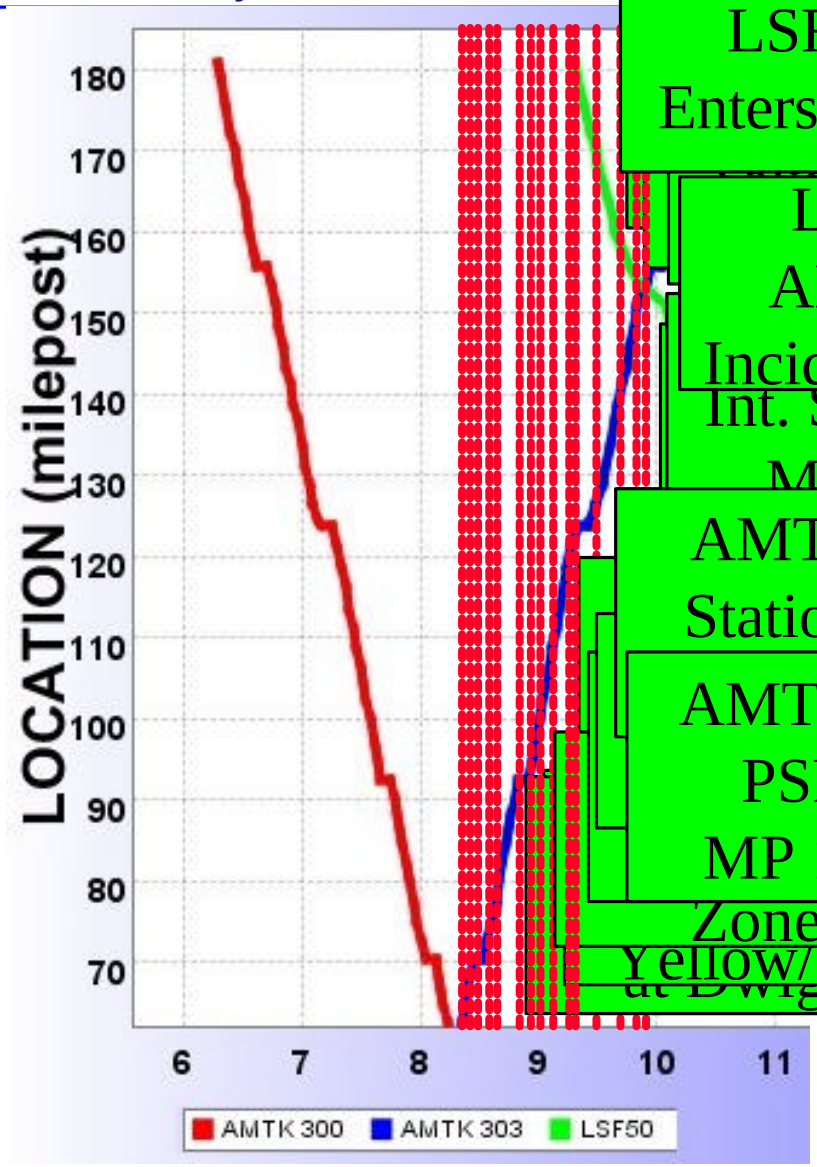
IDOT Chart for Saturday



A Day in the Safety Life of a Train System

- The following slides show a typical trip by two trains, and what interactions each train had as they come up to an eventual meet.

- String chart taken from the previous data for Wednesday, showing AMTK 303 and LSF 50



LSF 50
Enters Track

AMTK 303
Station Stop

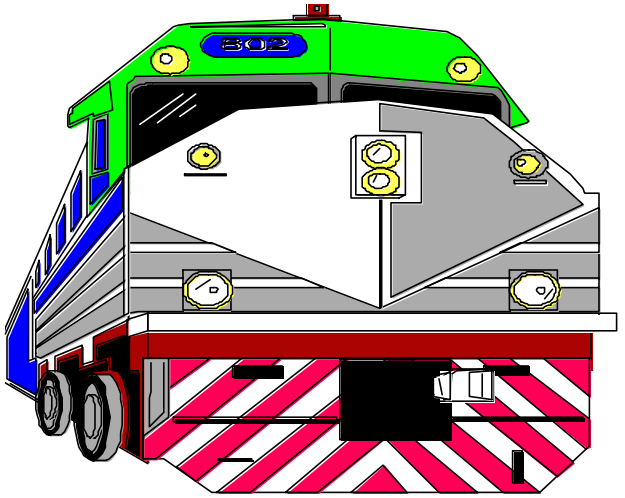
AMTK 303
PSR at
MP 126.3

Zone
Yellow/Red

Int. Signal
Control Point
µlok, µTrax

Dynamic
Model

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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ASCAP SAFETY BEHAVIOR MODELS

Dr. Lori M. Kaufman

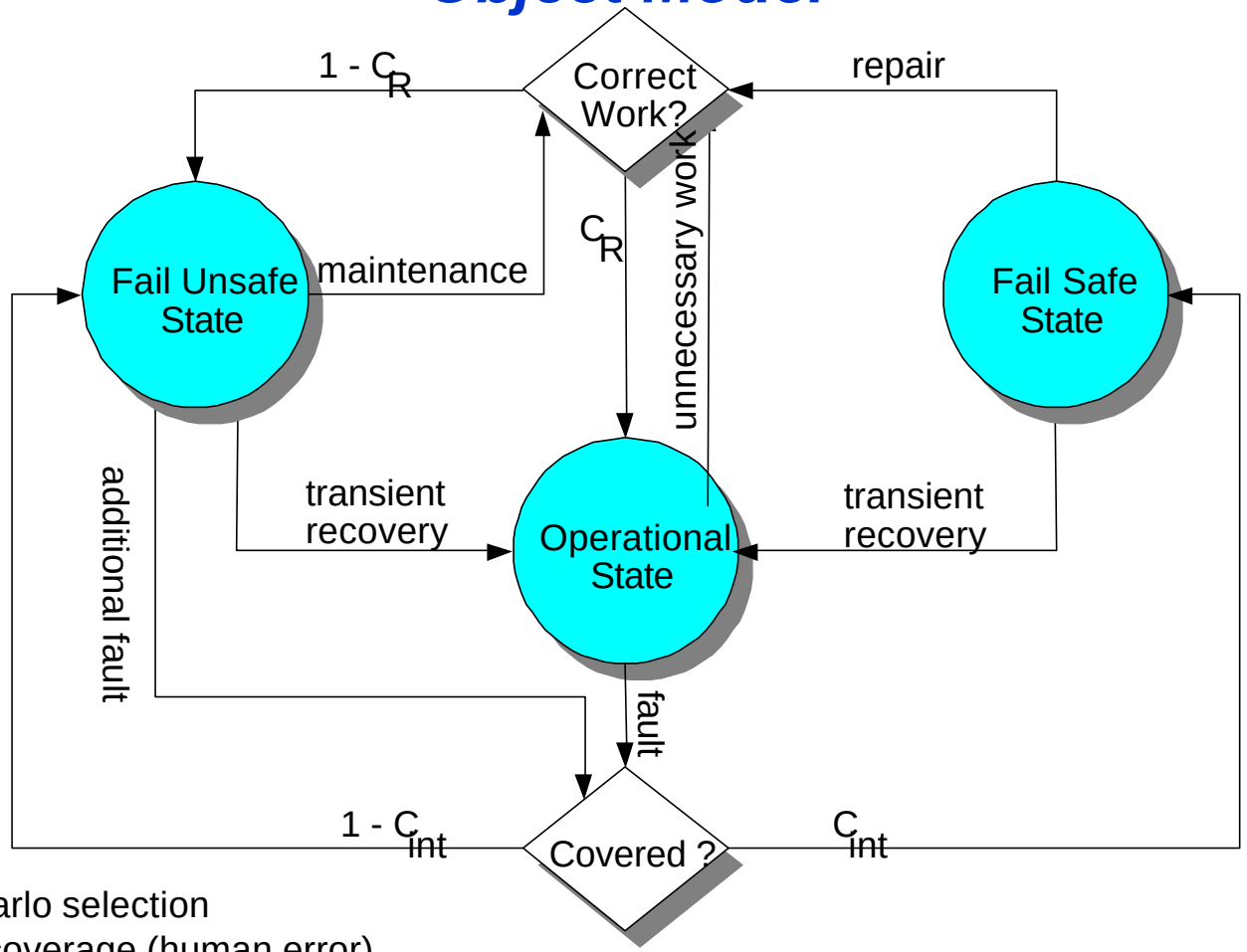
Train Movement Model (TMM)

- TMM is the foundation algorithm of ASCAP that determines Exposure
- Incorporates railroad schedules
  - Freight
  - Passenger
  - Work equipment
- Incorporates railroad scheduling practices
- Incorporates railroad operational procedures

Train Dynamic Model

- ASCAP partitions movement into three (3) distinct models
  - Average speed polynomial model
  - Linear acceleration/deceleration model
  - Dynamic movement model

Object Model



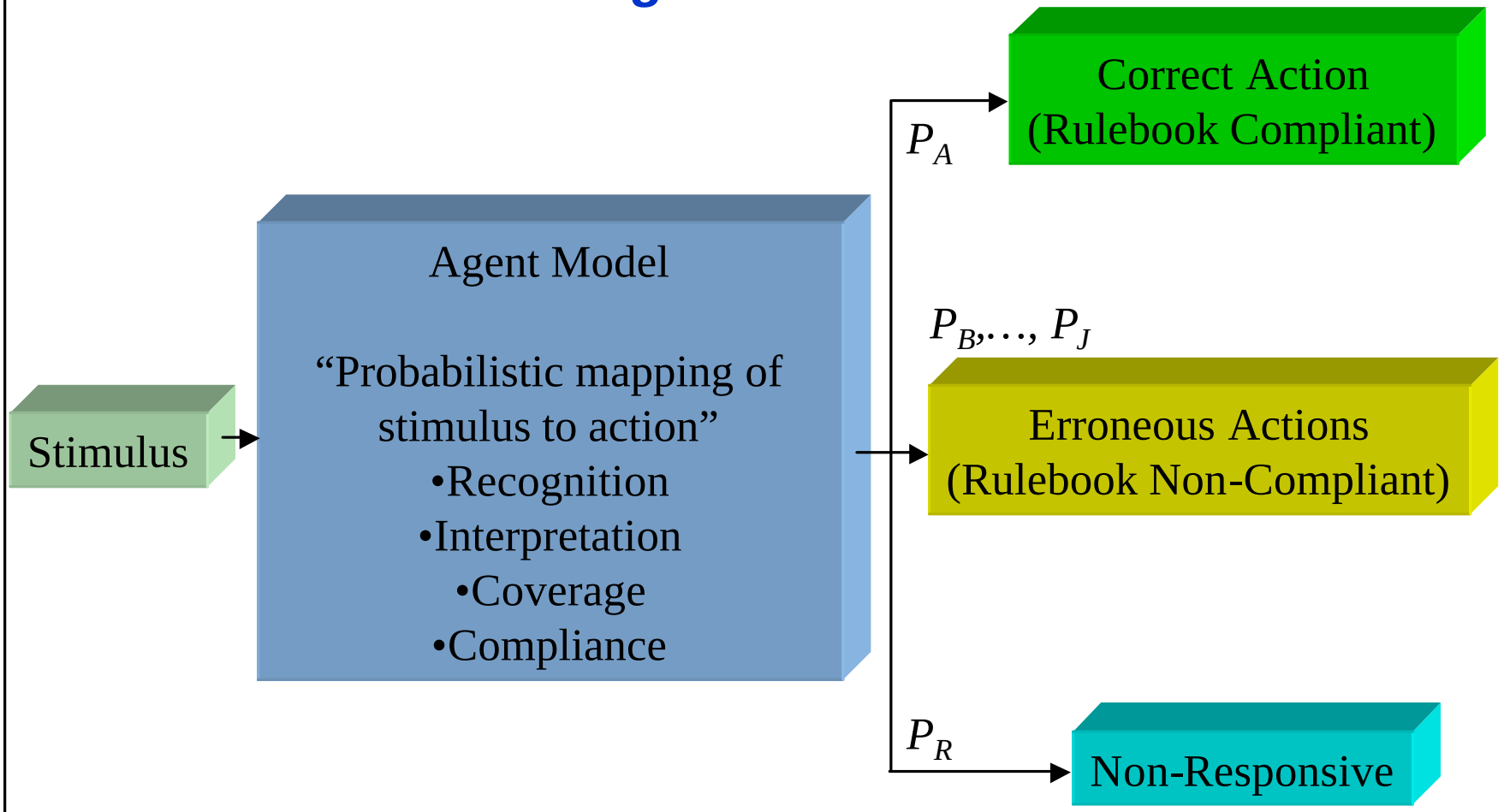
Legend

◇ Monte Carlo selection

C_R: Repair coverage (human error)

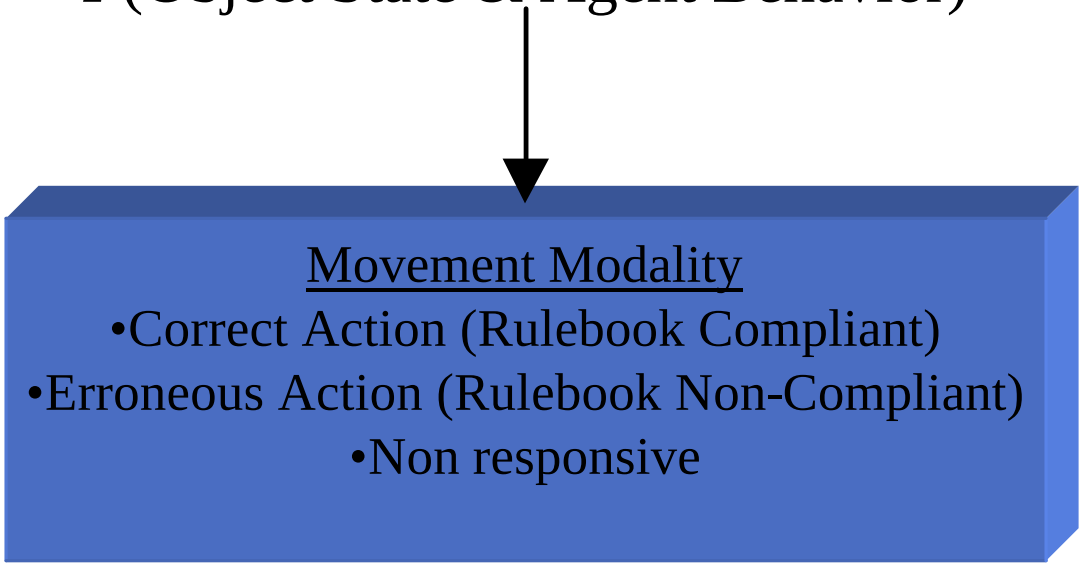
C_{int}: Internal fault coverage

Agent Model


Correct Action
(Rulebook Compliant)
P_A
Agent Model
"Probabilistic mapping of stimulus to action"
•Recognition
•Interpretation
•Coverage
•Compliance
Stimulus
$P_B, \ldots, P_J$
Erroneous Actions
(Rulebook Non-Compliant)
P_R
Non-Responsive

Knowledge Based Blackboards

F(Object State & Agent Behavior)



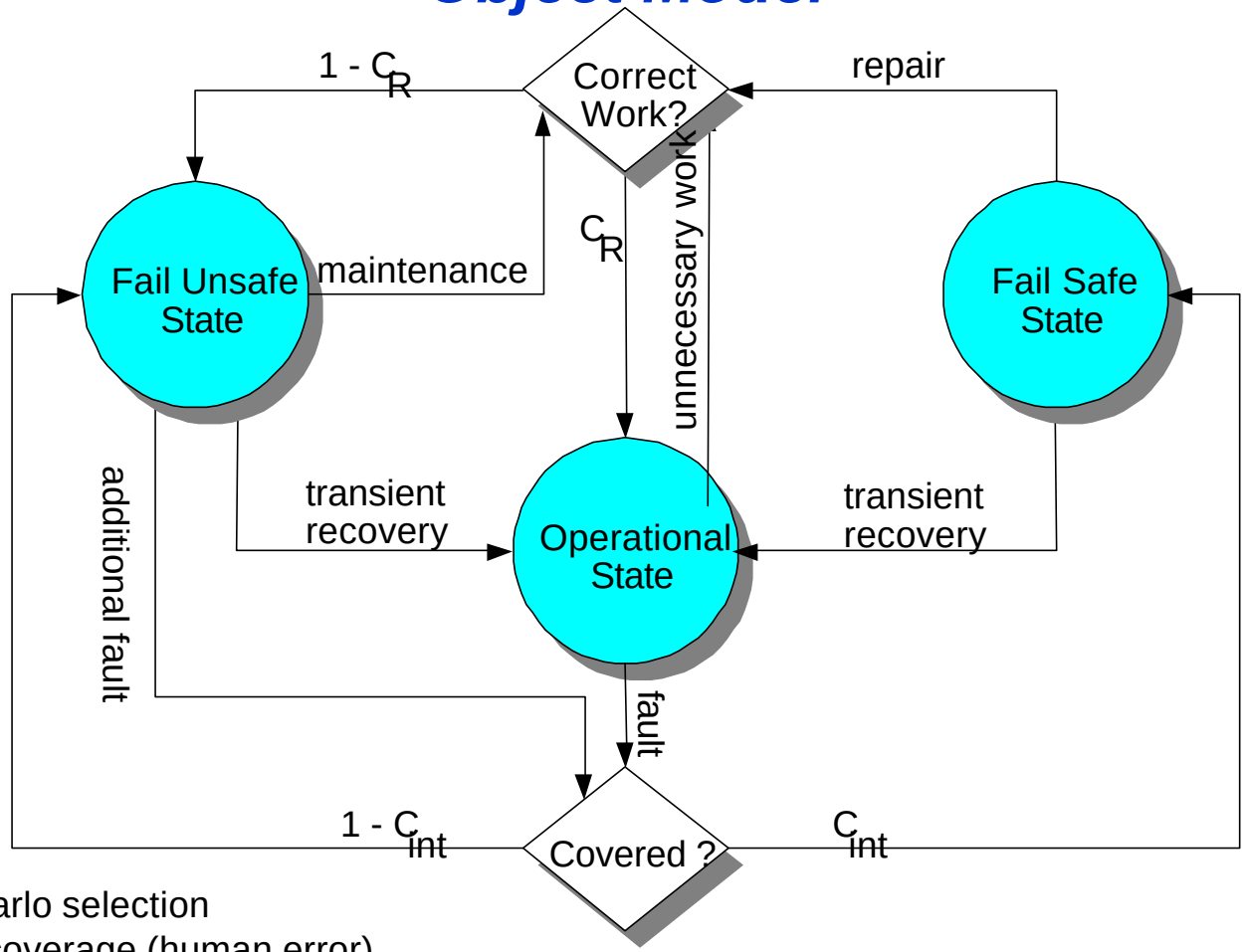
Events Passed at Danger (EPAD)

- Identify train exposure to either an agent violation or an object hazard
- Indicate the potential for an Incident/Accident condition
  - Simulation trigger to check Incident/Accident conditions
  - Either precede or are coincident with a Incident/Accident
  - EPAD's equivalent to PHA list
- EPAD log content derived from FRA and NTSB accident report forms
- Evolving enhancements per FRA guidance
  - Code Yellow
  - Code Red

Safety Model Integration

- ASCAP integrates safety models
  - Simulation process defines movement
- Typical Agent-to-Object example
  - 3-Lamp Control Point Signal

Object Model



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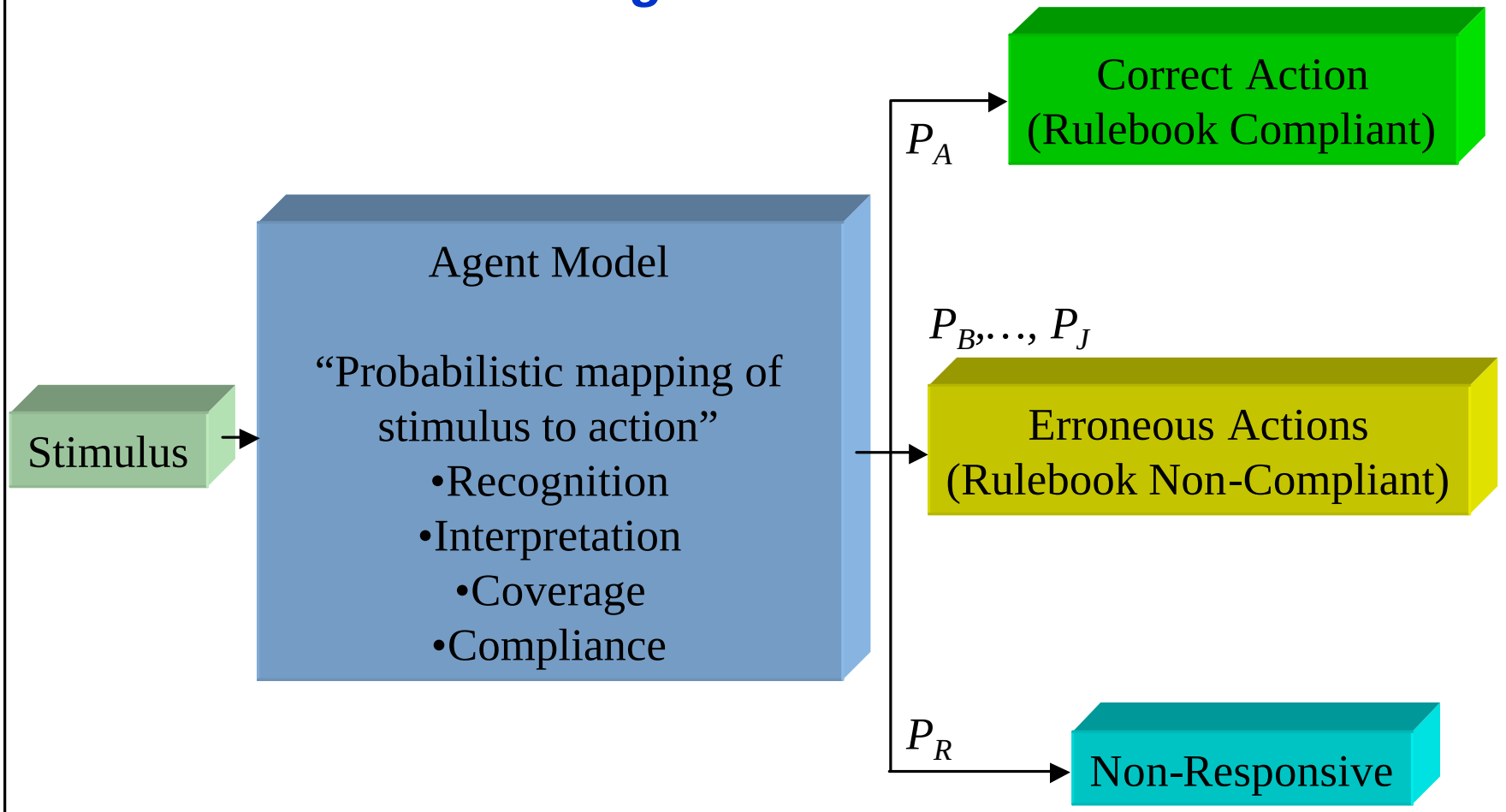
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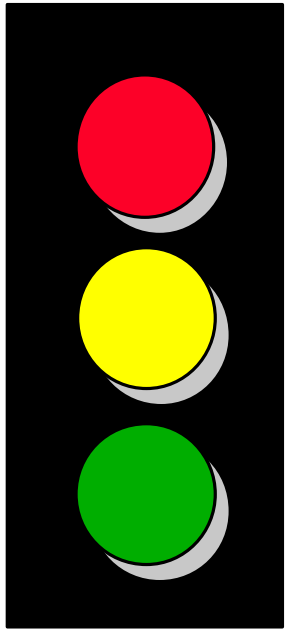
Erroneous Actions
(Rulebook Non-Compliant)
P_R
Non-Responsive

3-Lamp Control Point Signal

- Single signal head
  - Three (3) lamps
    - Red
    - Yellow
    - Green
  - Five (5) permissible aspects
    - Red
    - Flashing Red
    - Yellow
    - Flashing Yellow
    - Green



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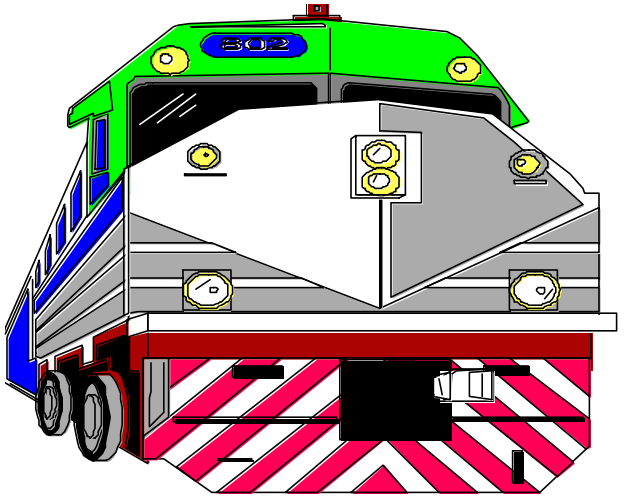

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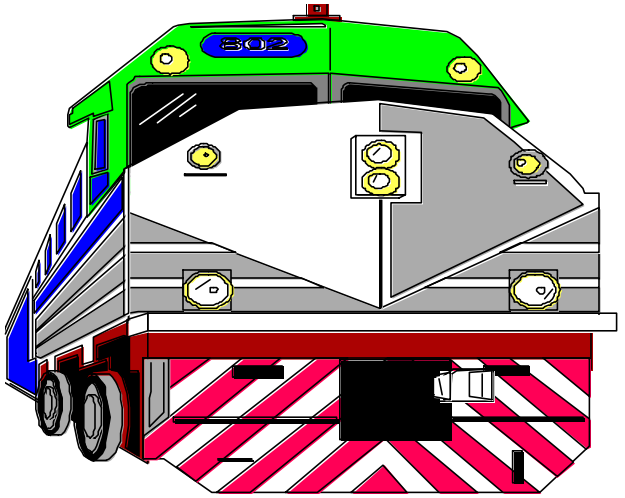

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Acknowledgements

The development of the Axiomatic Safety-Critical Process (ASCAP) has been supported and made possible by the following Sponsors:

- Railroad Safety Advisory Committee (RSAC) PTC Standards Working Group
- CSX Railroad Communication-based Traffic Control (CBTM)
- Federal Railroad Administration ASCAP++
- New York City Transit (NYCT) Communication-based Train Control (CBTC)
- Lockheed Martin IDOT Positive Train Control (PTC)
- Maglev, Inc. Transrapid “Pennsylvania Project”

The ASCAP Peer Review Process has been supported by the FRA, Labor, Railroads, Suppliers and International University Collaboration. The “Peer Review” purpose is to insure the “Adequacy and Calibration” of Application-specific ASCAP Design for Safety Assessment (s).

Presenters

Dr. Ted C. Giras, Director of the Center of Rail Safety-Critical Excellence

Dr. Ronald D. Williams, Deputy Director of the Center of Rail Safety-Critical Excellence, WEB-based ASCAP Cluster Computer Laboratory

Dr. Lori M. Kaufman, Railroad Design for Safety Assessment Team Leader, Lockheed Martin Positive Train Control (PTC) Program Manager

Mr. Marc E. Monfalcone, IDOT ASCAP Simulation Software Integrator

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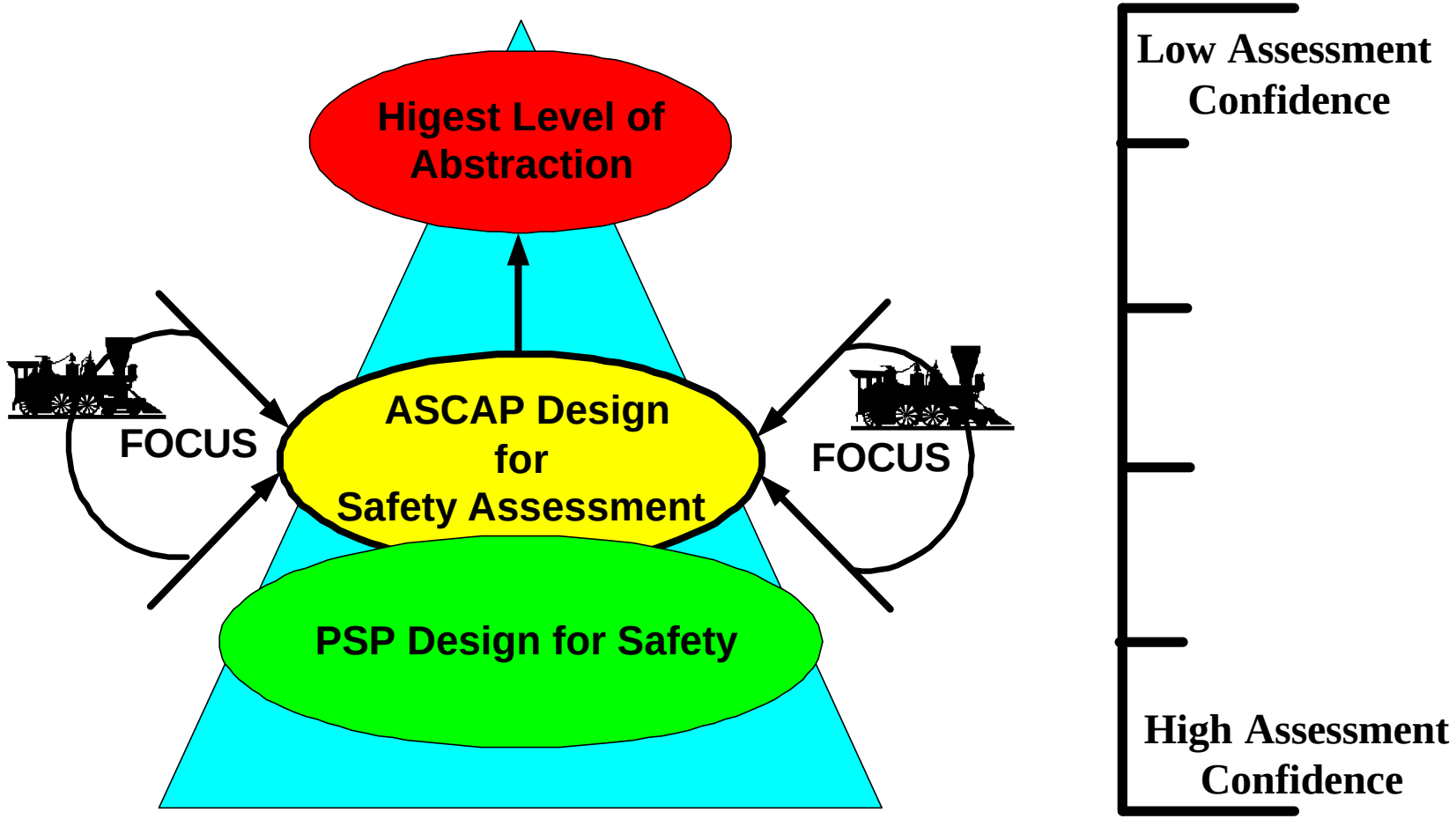
ASCAP Design for Safety Assessment Focus

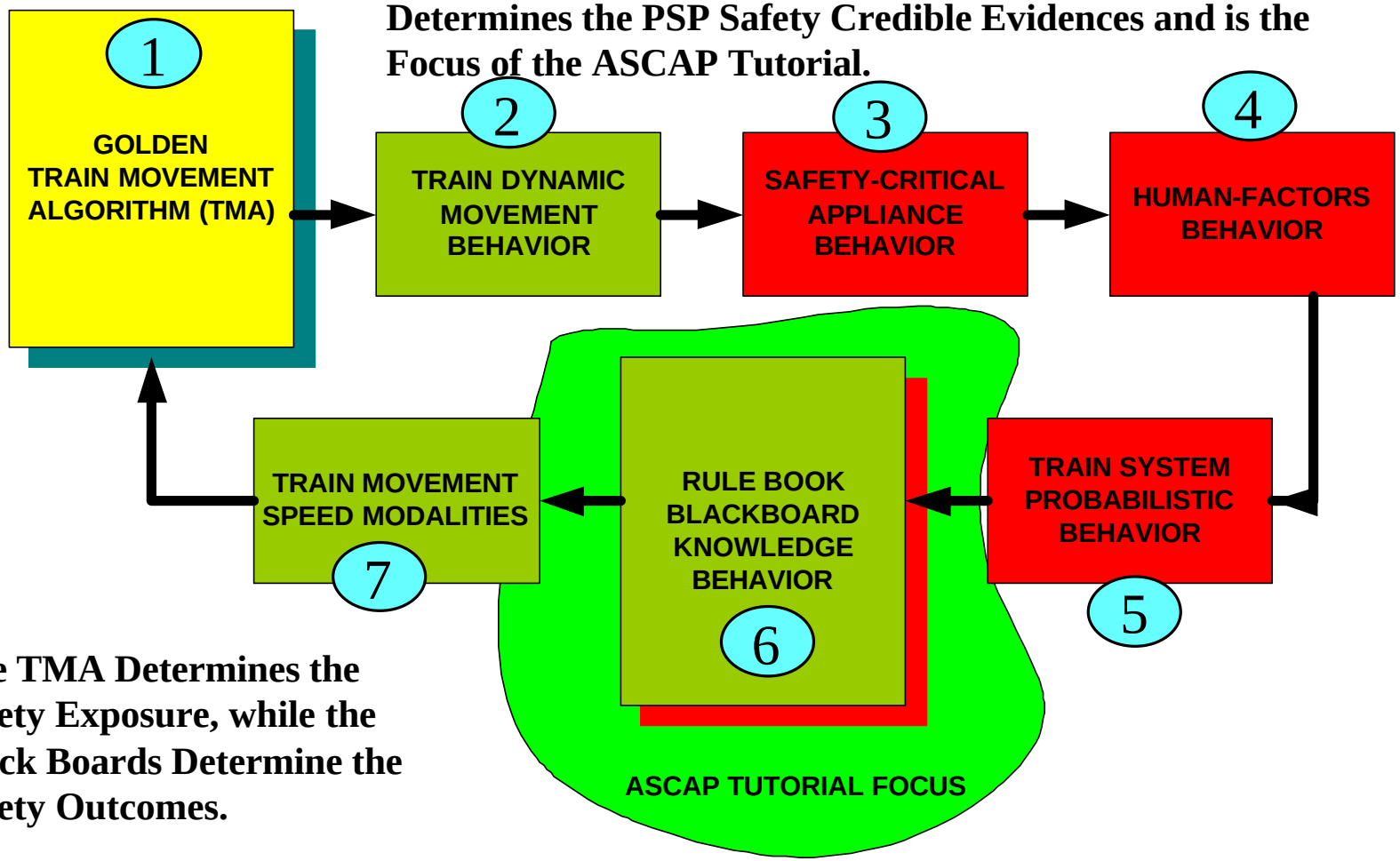


Basic Principles of Design for Safety Assessment

- Large-scale Train Movement Stochastic Simulation Determines the Safety Exposure
- Track Infrastructure and Physical Safety Appliances are Object-oriented
- Dispatcher, Train Crews and Roadway Workers are Agent-oriented
- ASCAP N-Train Methodology is Train-centric to Mitigate Safety State Explosion
- Monte Carlo Stochastic Demand-Intersection Safety Simulation Methodology
- Train Dynamic Movement: Discrete Event and Continuous Simulation
- Rule Book Knowledge-based Compliance and Non-Compliance: A Knowledge-based Blackboard Approach that Determines Train Speed Modalities
- Events Passed at Danger Logging Equivalent to Fault Trees
- ASCAP Implementation is Unified Modeling Language (UML) Compliant

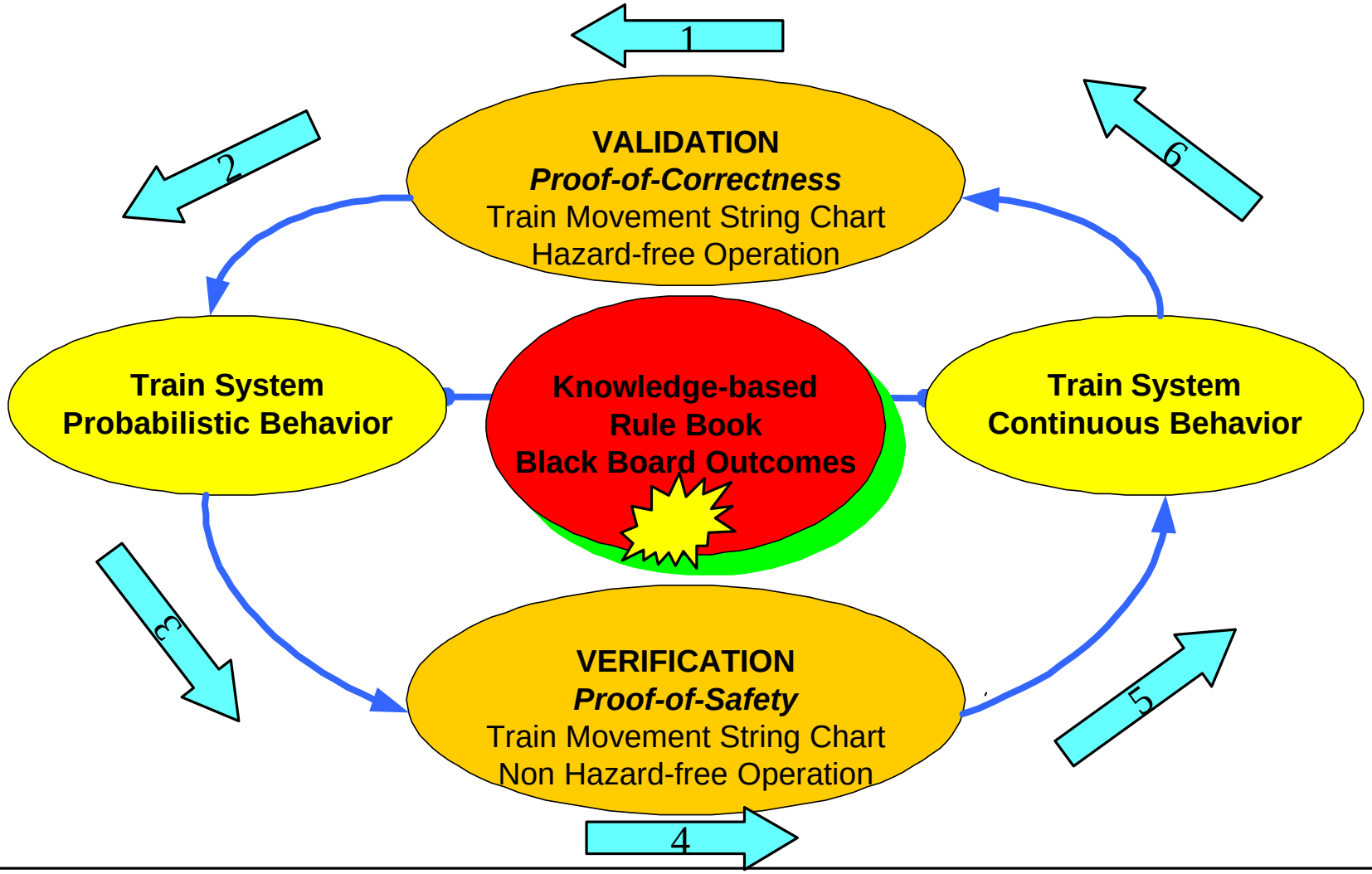
…A Control System Simulation View of ASCAP

The Rule Book Black Board Knowledge-based Behavior Determines the PSP Safety Credible Evidences and is the Focus of the ASCAP Tutorial.



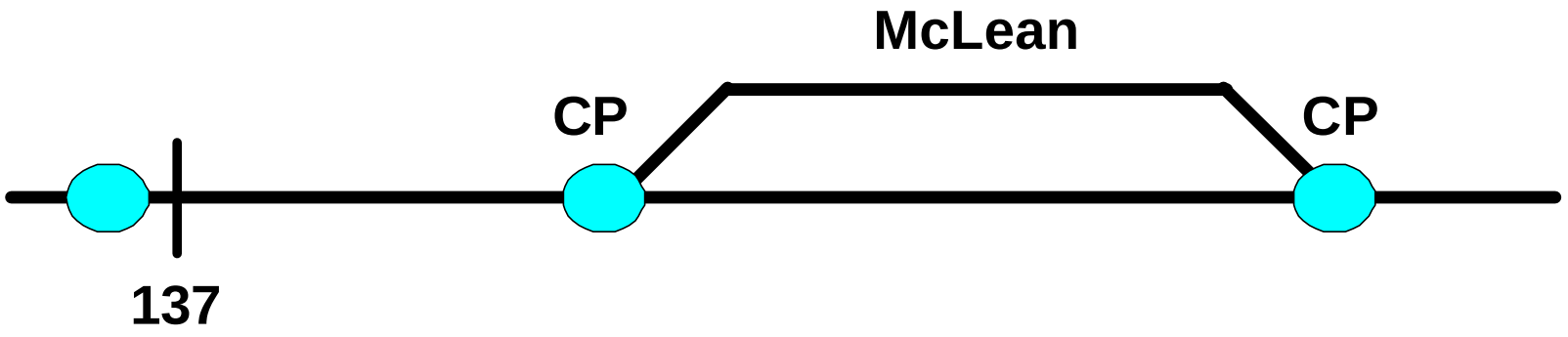
The TMA Determines the Safety Exposure, while the Black Boards Determine the Safety Outcomes.

Typical PSP Credible Evidences Evaluation Process

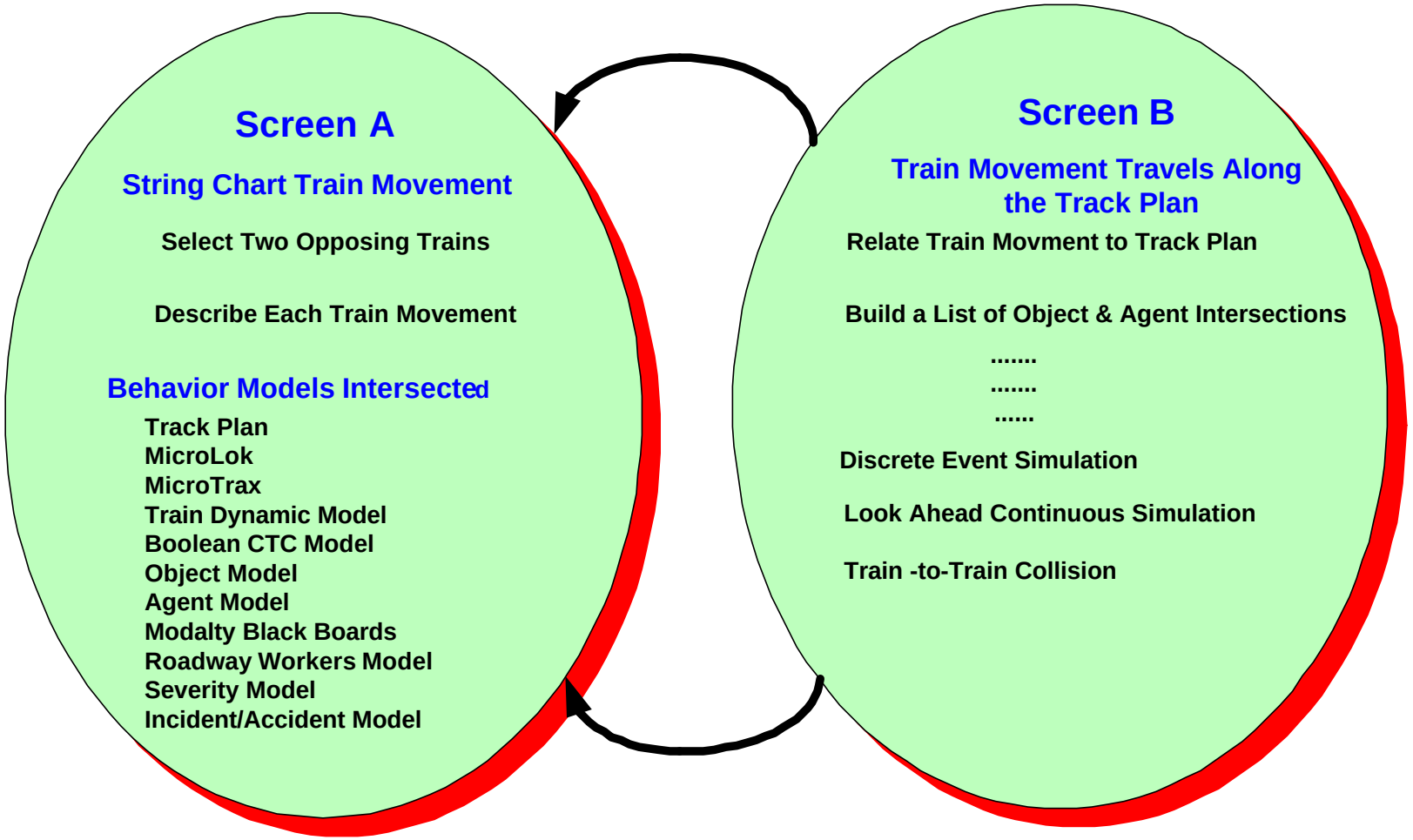


How Do We Obtain Safety Credible Evidences ?

…….A DAY IN THE SAFETY STATE DEMANDS OF A TRAIN SYSTEM……..



Dual Train Movement Scenario



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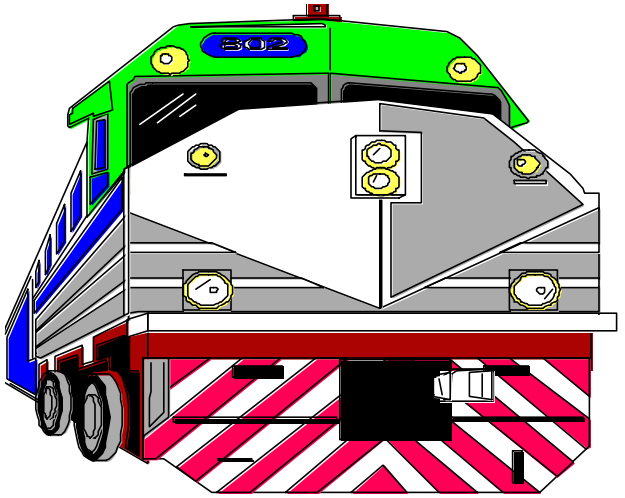

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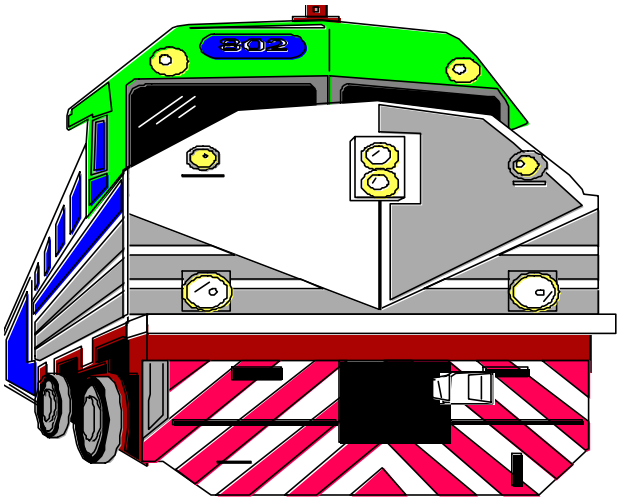

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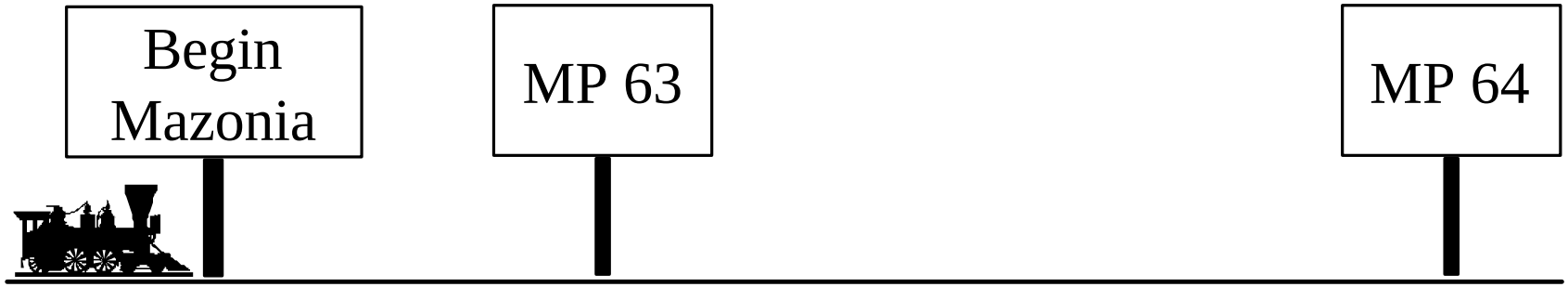
A Day in the Safety Life of a Train System

- The following slides show a typical trip by two trains, and what interactions each train had as they come up to an eventual meet.
- This presentation identifies the interactions between objects and agents for each of the trains.

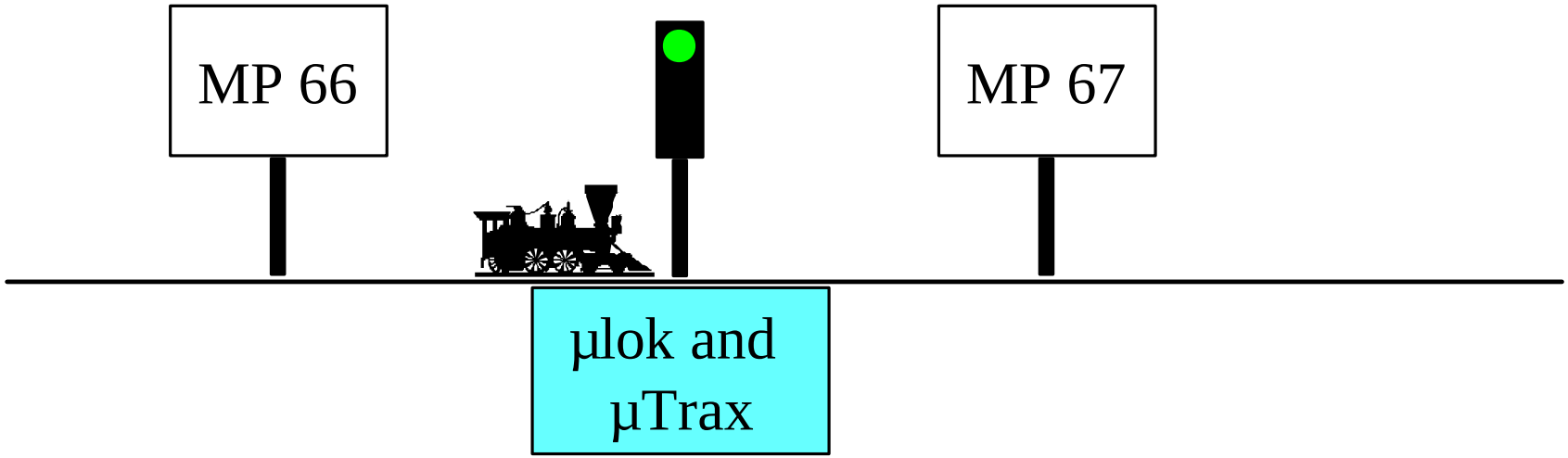
AMTK 303 Enters Track

- Train Crew asks Dispatcher for permission to enter territory.
- Dispatcher looks ahead for other traffic and assigns route to AMTK 303.
- Train crew accelerates to posted speed.
- Models Intersected: Dispatcher, Train Crew, TMM



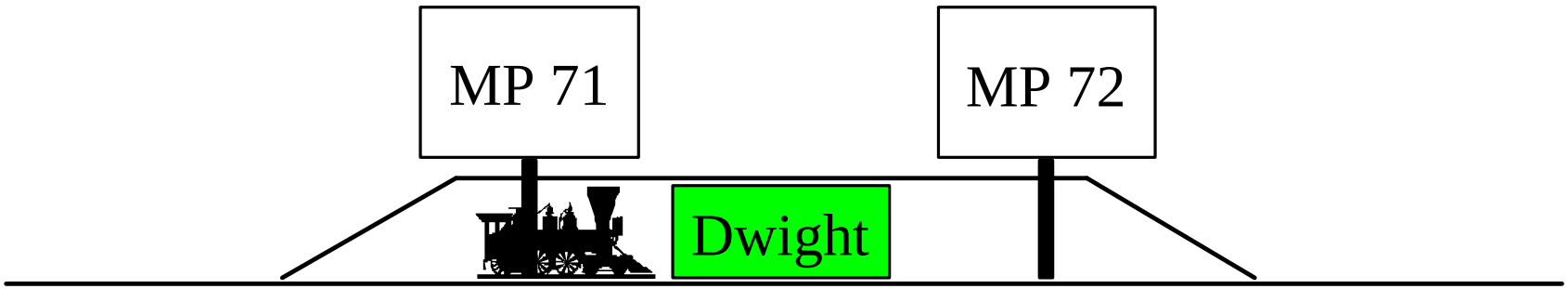
AMTK 303 – Intermediate Signal at MP 66.5

- Train crew recognizes “Proceed” aspect displayed on intermediate signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- Models Intersected: Signal, Microlok, MicroTrax, Train Crew



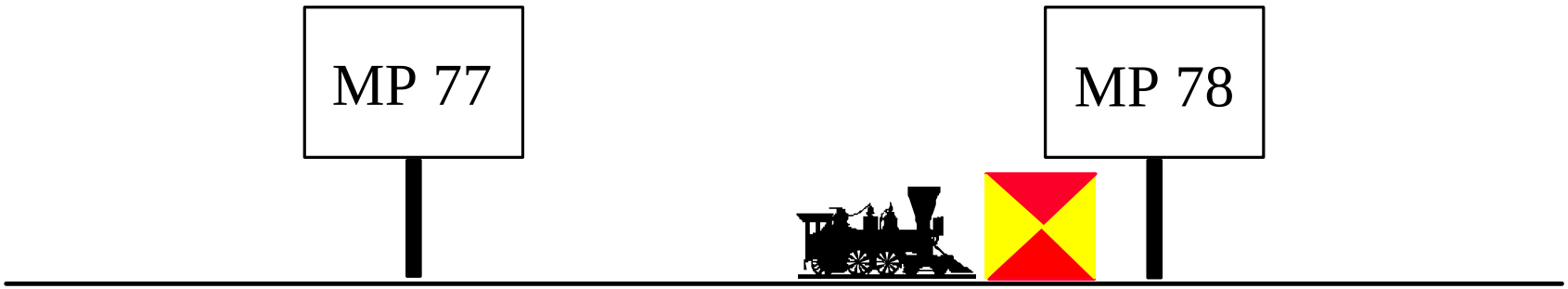
AMTK 303 – Station Stop at Dwight

- AMTK 303 has a short stop at Dwight.
- After waiting, 303 restarts route.
  - Routing decisions may have been updated while train was stopped.
- Models Intersected: Train Crew



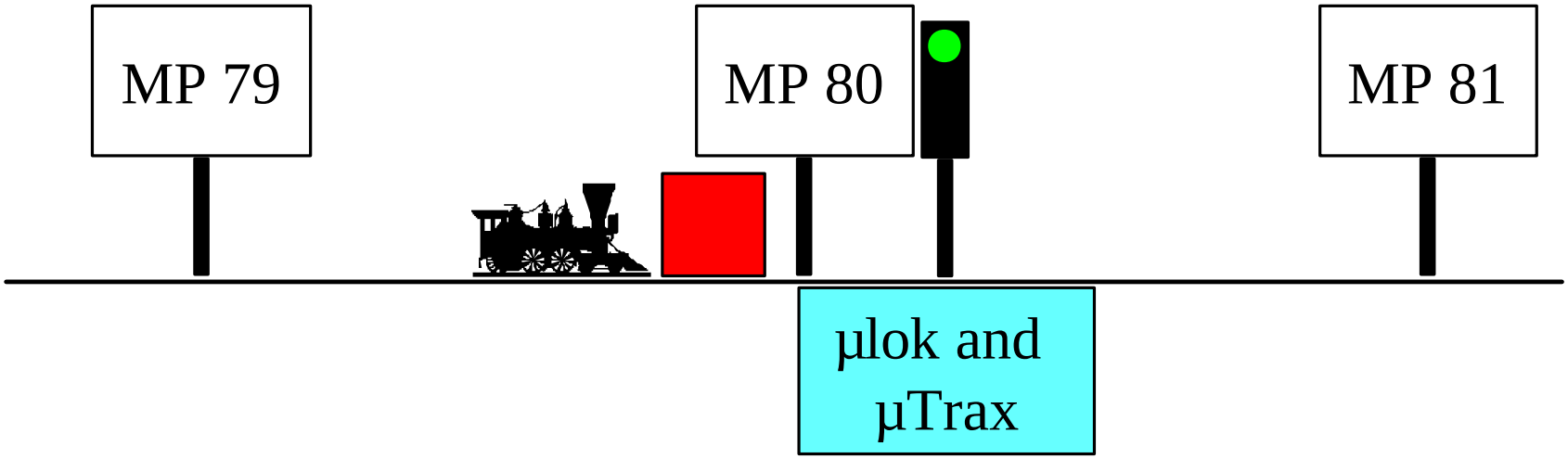
AMTK 303 – Sees Yellow/Red Flag

- Train crew sees Yellow/Red flag on wayside, corresponding to work zone ahead.
  - GCOR 5.4.3: Place a yellow-red flag two (2) miles before the restricted area.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - GCOR 5.4.3: Crew members must be prepared to stop short of a red flag in two (2) miles.
- Models Intersected: Work Crew, Train Crew



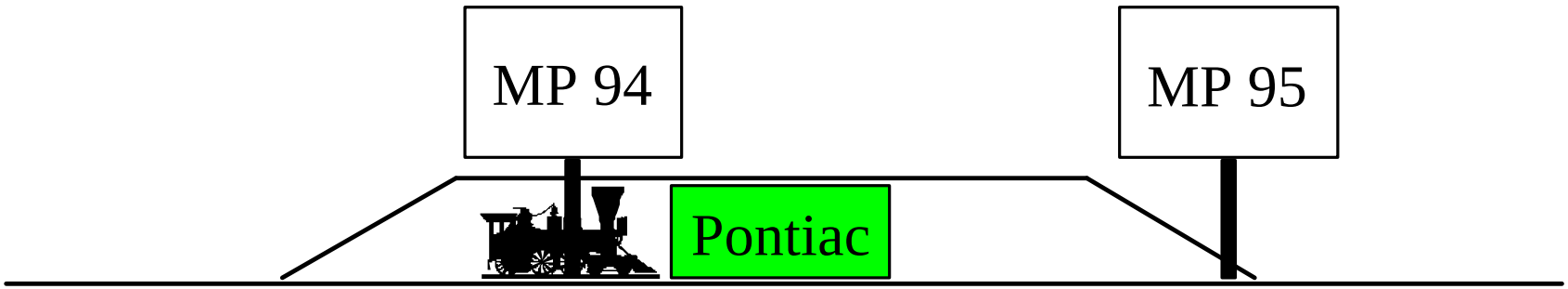
AMTK 303 – Enters Work Zone

- Train Crew Response: Correct Action (Rulebook Compliant)
  - GCOR 5.4.7: Train must stop short of red flag
  - GCOR ?: Contact dispatcher for permission to enter work zone.
- Dispatcher Response: Correct Action (Rulebook Compliant)
  - GCOR ?: Allow train to pass at restricted when track cleared
- Train Crew Response: Correct Action (Rulebook Compliant)
  - GCOR ?: Travel at restricted speed set by EIC until rear of train passes end of restricted area
- Models Intersected: Work Crew, Train Crew, Work Crew EiC, Work Zone



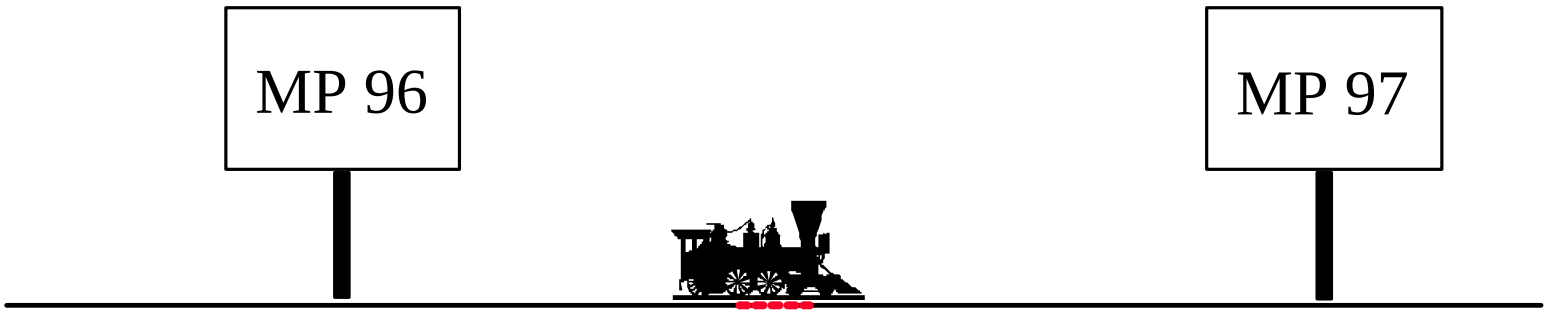
AMTK 303 – Station Stop at Pontiac

- AMTK 303 has a short stop at Pontiac.
- After waiting, 303 restarts route.
  - Routing decisions may have been updated while train was stopped.
- Models Intersected: Train Crew



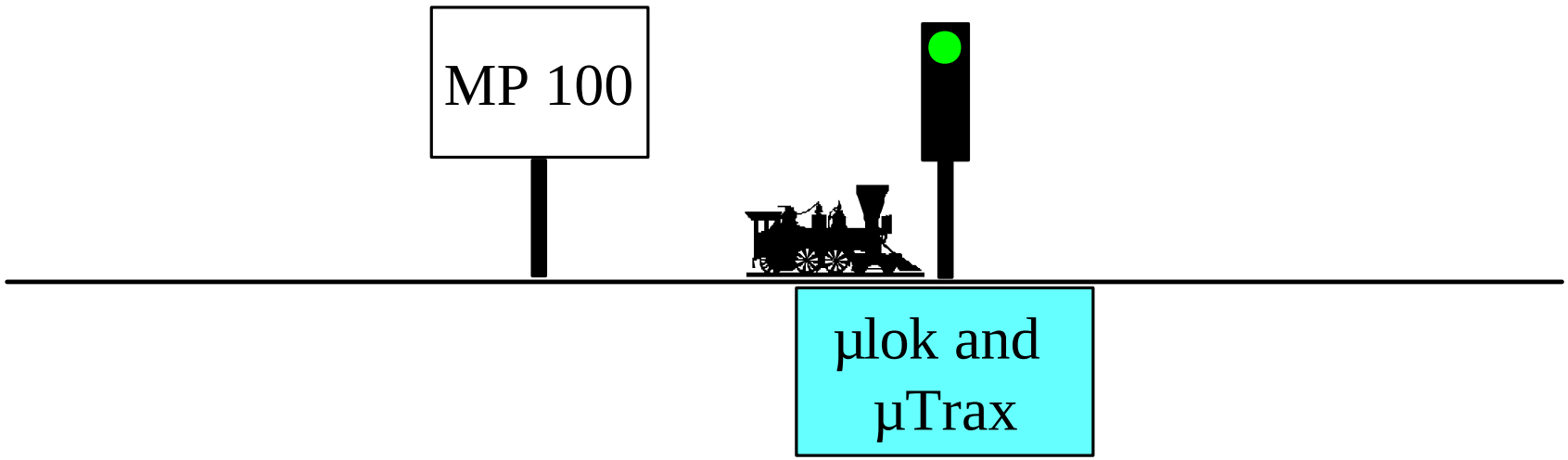
AMTK 303 – Intersection with FUS Rail

- Broken rail object model has determined that the rail has failed unsafely under AMTK 303.
- However, the model determines that no incident/accident results from the rail break, and movement continues.
- Models Intersected: Broken Rail



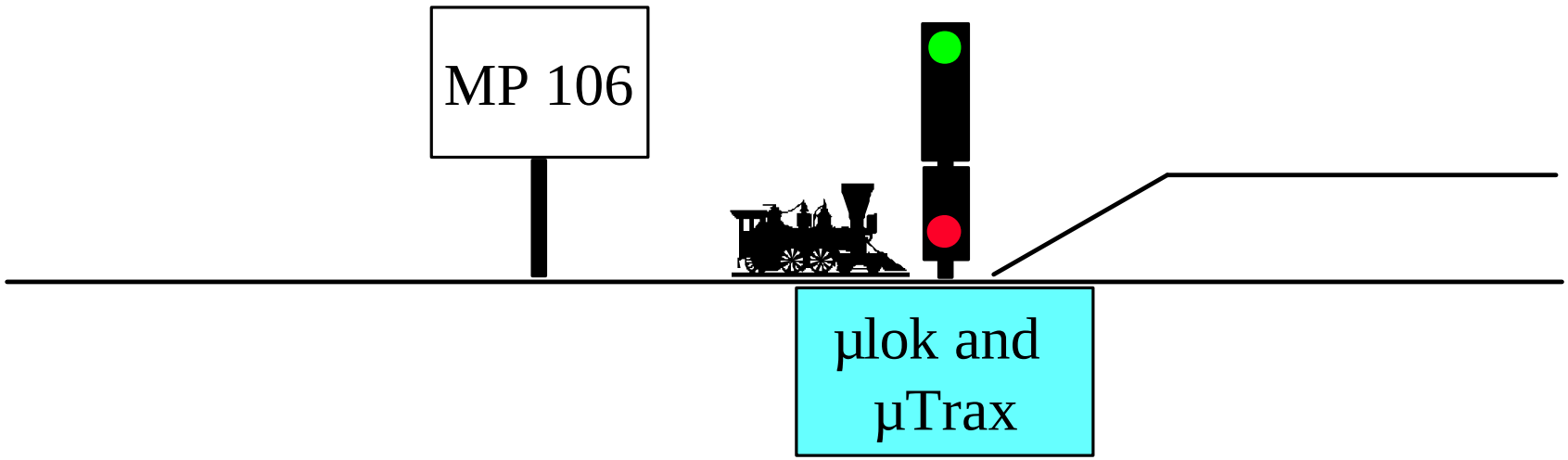
AMTK 303 – Intermediate Signal at MP 100.3

- Train crew recognizes “Proceed” aspect displayed on intermediate signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- Models Intersected: Signal, Microlok, MicroTrax, Train Crew



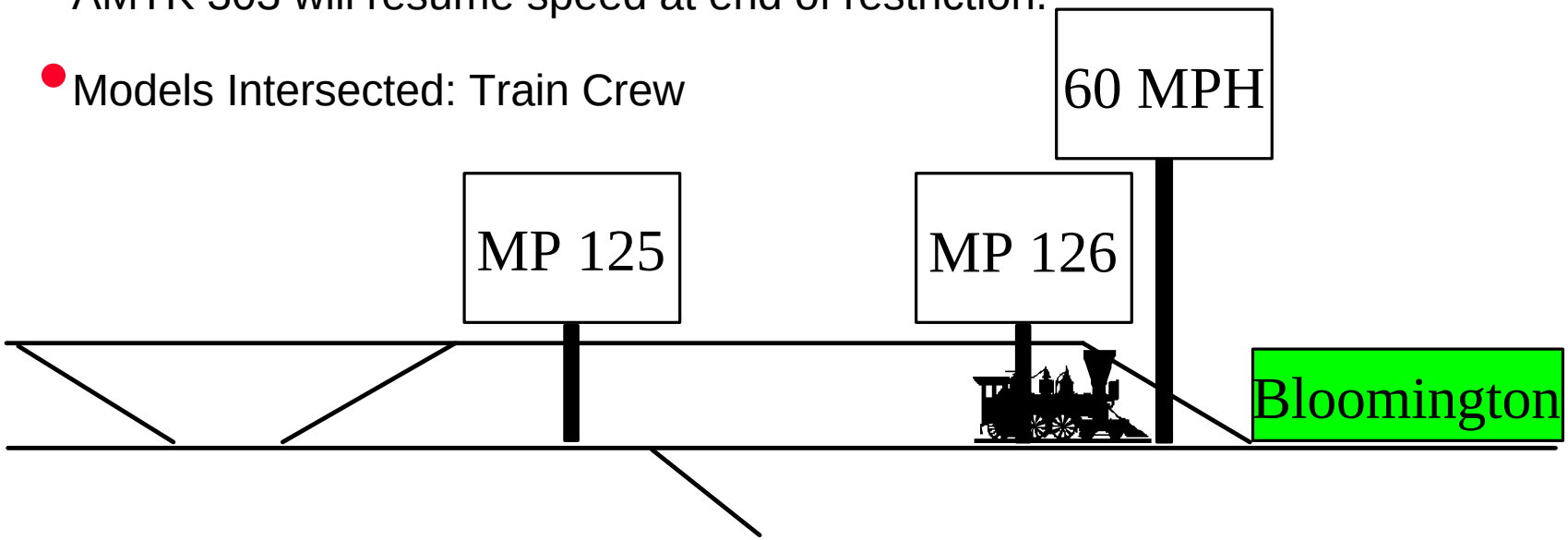
AMTK 303 – Control Point at Ballard

- Train crew recognizes “Proceed” aspect displayed on 5-Lamp Control Point signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- Models Intersected: Control Point, Switch, Microlok, MicroTrax, Train Crew, Dispatcher



AMTK 303 – Permanent Speed Restriction at MP 126.3

- Train crew recognizes permanent speed restriction of 60 MPH when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- AMTK 303 will resume speed at end of restriction.
- Models Intersected: Train Crew

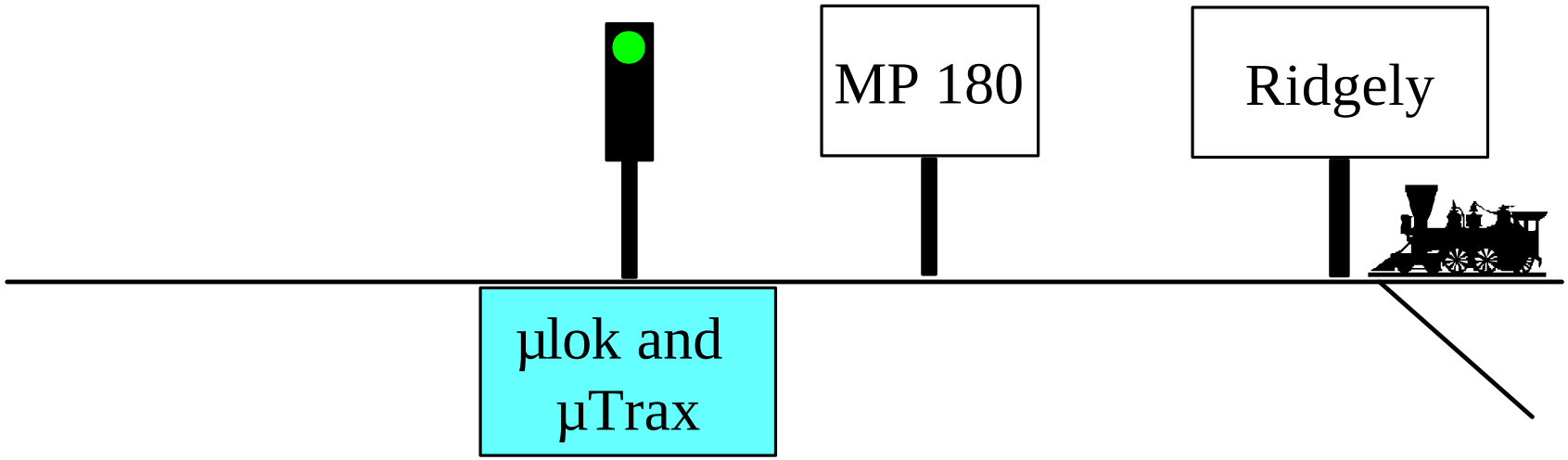


LSF 50 Enters Track

- Train Crew asks Dispatcher for permission to enter territory.
- Dispatcher looks ahead for other traffic and assigns route to LSF 50

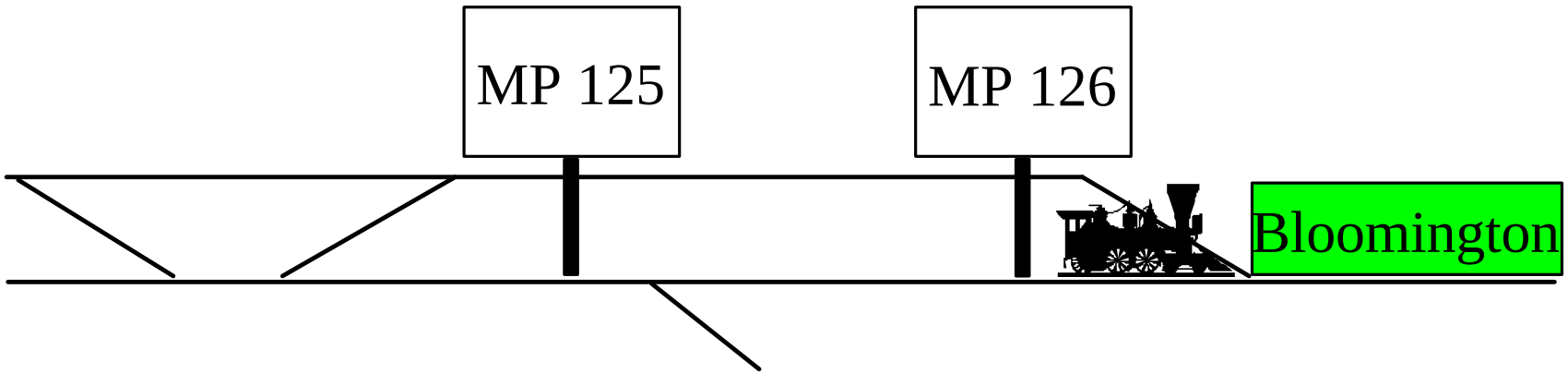
Preparing for meet with AMTK 303

- Models Intersected: Train Crew, Dispatcher, TMM



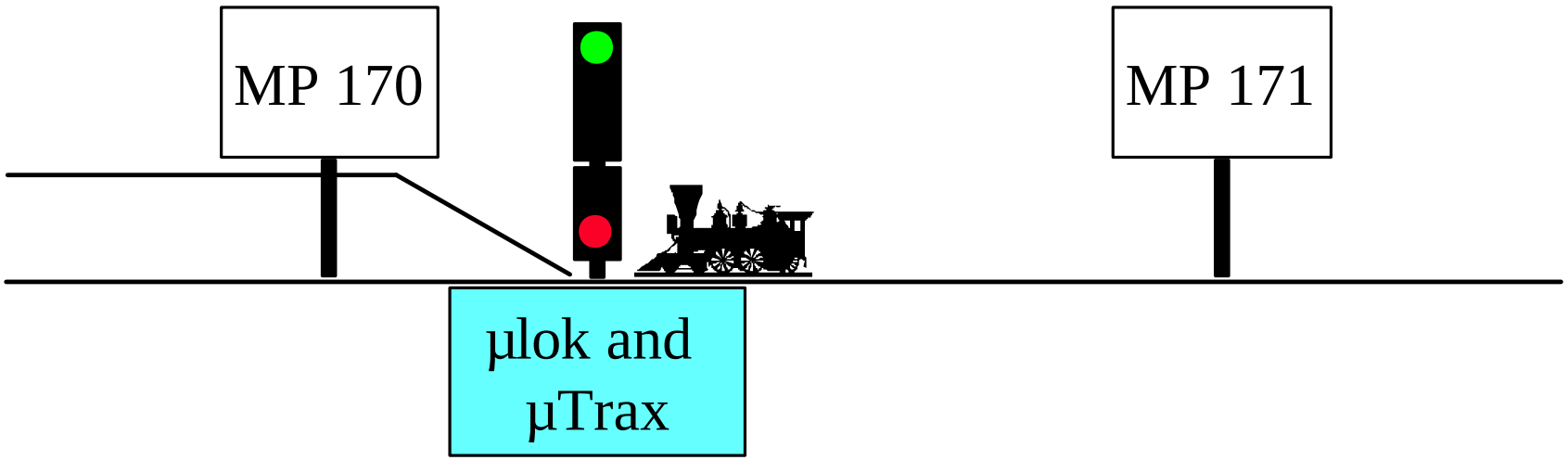
AMTK 303 – Station Stop at Bloomington

- AMTK 303 has a short stop at Bloomington.
- After waiting, 303 restarts route.
  - Routing decisions may have been updated while train was stopped.
- Models Intersected: Train Crew



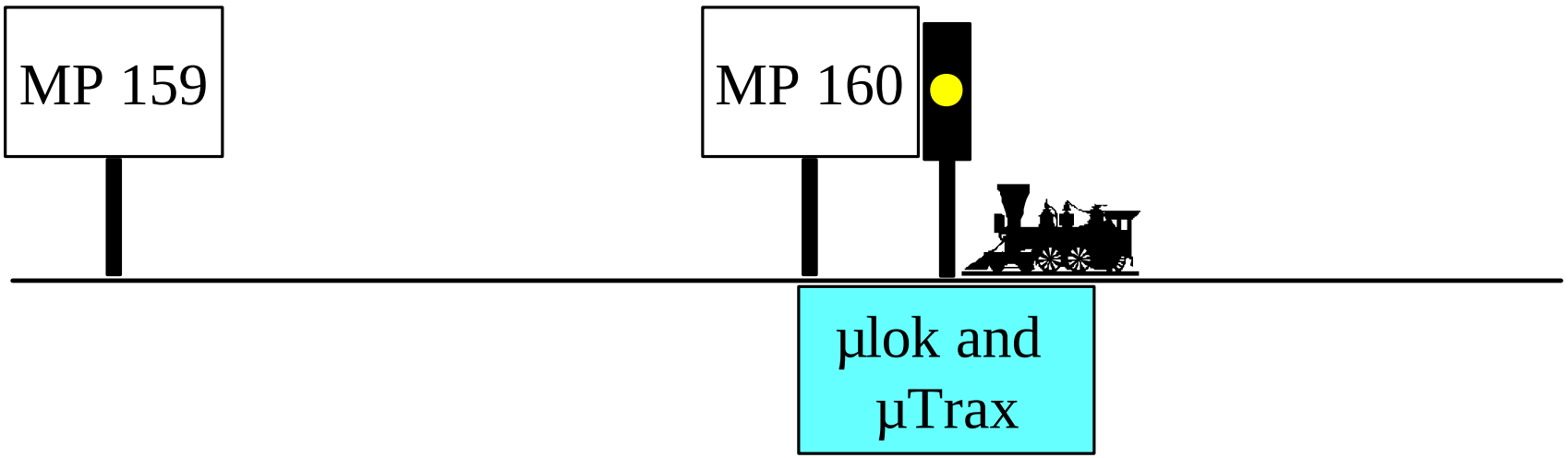
LSF 50 – Control Point at Elkhart

- Train crew recognizes “Proceed” aspect displayed on 5-Lamp Control Point signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- Models Intersected: Control Point, Switch, Microlok, MicroTrax, Train Crew, Dispatcher



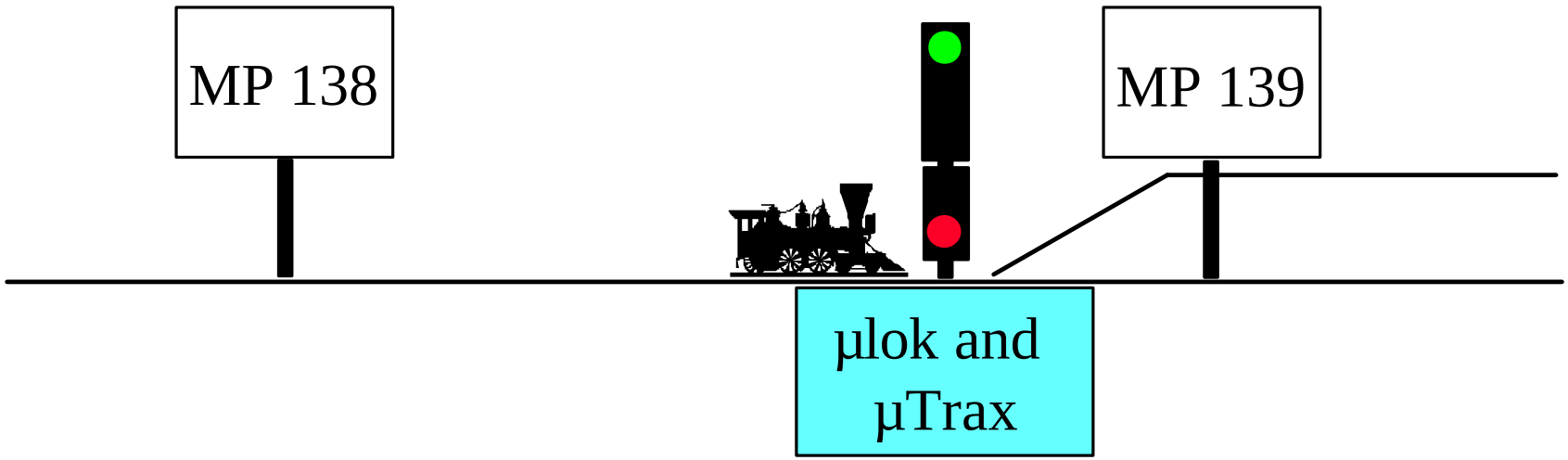
LSF 50 – Intermediate Signal at MP 160

- Train crew recognizes "Approach" aspect displayed on intermediate signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.5: Proceed prepared to stop before any part of train or engine passes the next signal. Freight trains exceeding 30 MPH must immediately reduce to 30 MPH. Passenger trains exceeding 45 MPH must immediately reduce to 45 MPH.
- Models Intersected: Signal, Microlok, MicroTrax, Train Crew



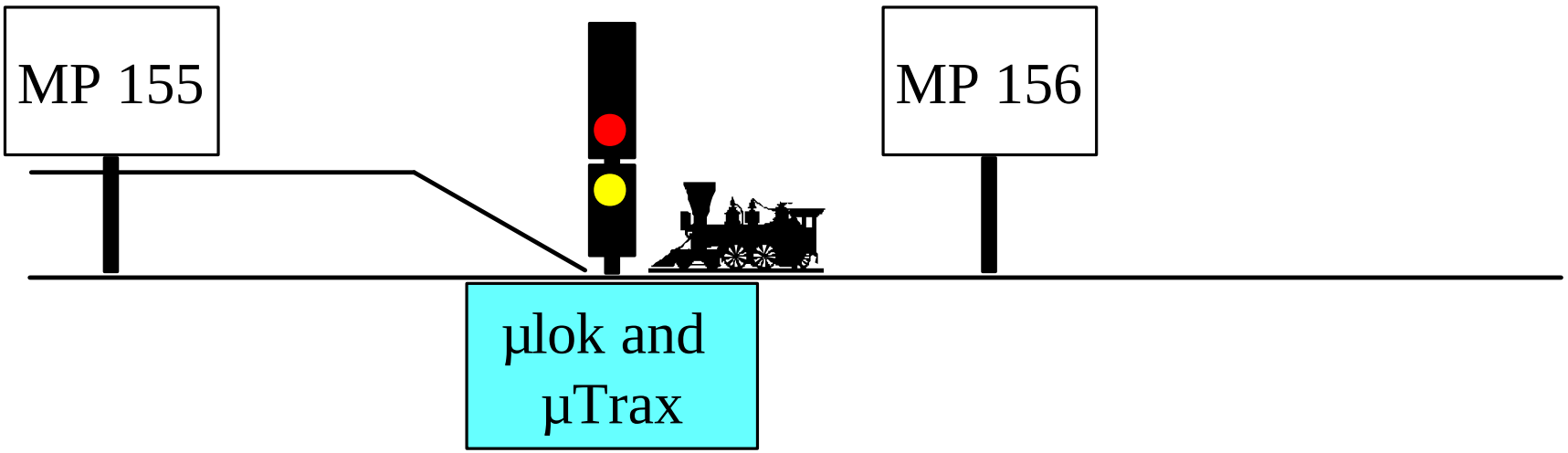
AMTK 303 – Control Point at McLean

- Train crew recognizes “Proceed” aspect displayed on 5-Lamp Control Point signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- Models Intersected: Control Point, Switch, Microlok, MicroTrax, Train Crew, Dispatcher



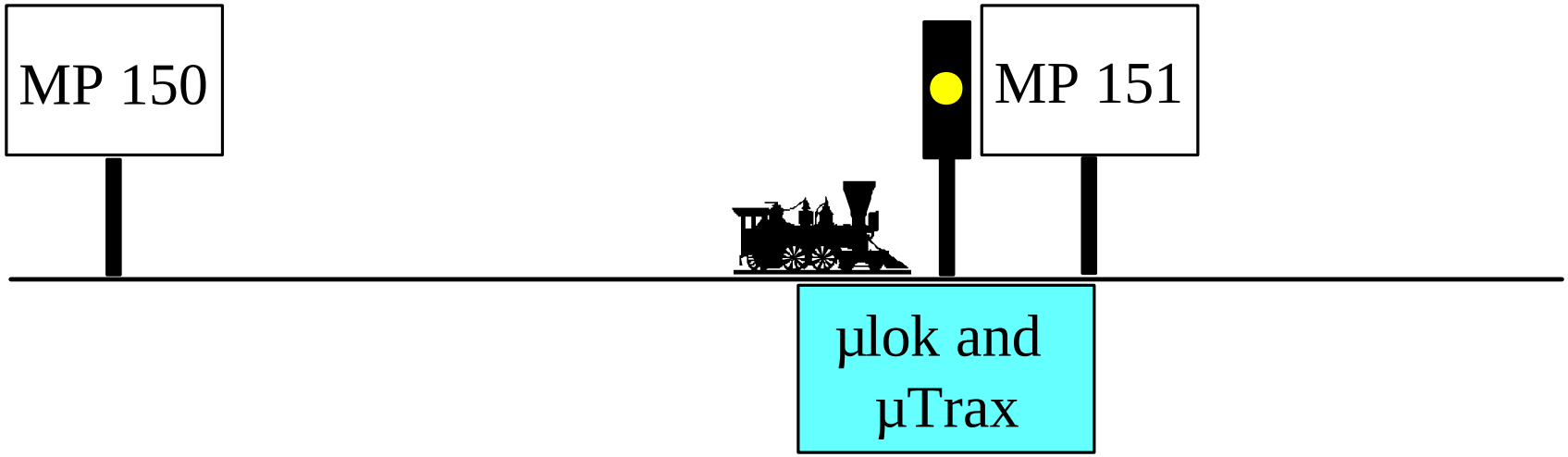
LSF 50 – Takes Siding at Athol

- Train crew recognizes “Approach Diverging” aspect displayed on 5-Lamp Control Point signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.10: Proceed on diverging route at prescribed speed through turnout prepared to stop before any part of train or engine passes the next signal. Freight trains exceeding 30 MPH must immediately reduce to 30 MPH. Passenger trains exceeding 45 MPH must immediately reduce to 45 MPH
- Models Intersected: Control Point, Switch, Microlok, MicroTrax, Train Crew, Dispatcher



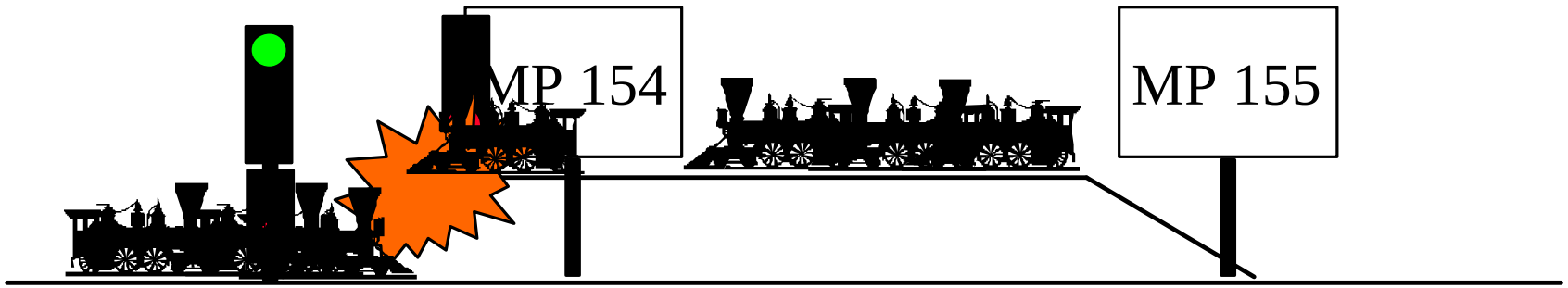
AMTK 303 – Intermediate Signal at MP 151

- Train crew recognizes “Approach” aspect displayed on intermediate signal when they enter visual range.
- Train Crew Response: Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.5: Proceed prepared to stop before any part of train or engine passes the next signal. Freight trains exceeding 30 MPH must immediately reduce to 30 MPH. Passenger trains exceeding 45 MPH must immediately reduce to 45 MPH.
- Models Intersected: Signal, Microlok, MicroTrax, Train Crew



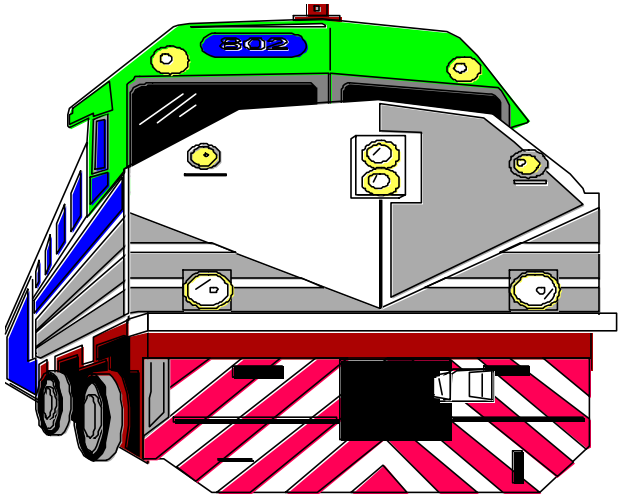
LSF 50 & AMTK 303 – Incident at Athol

- AMTK 303 notes "Proceed" aspect on signal.
  - Correct Action (Rulebook Compliant)
  - UPRR Special Instruction 9.2.1: Proceed at posted speed
- LSF 50 is not responsive to siding signal
  - Continue at current speed



µlok and
µTrax

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



ASCAP TUTORIAL

MARCH 4, 2003
Philadelphia

ASCAP SAFETY BEHAVIOR MODELS

Dr. Lori M. Kaufman

ASCAP Safety Behavior Models

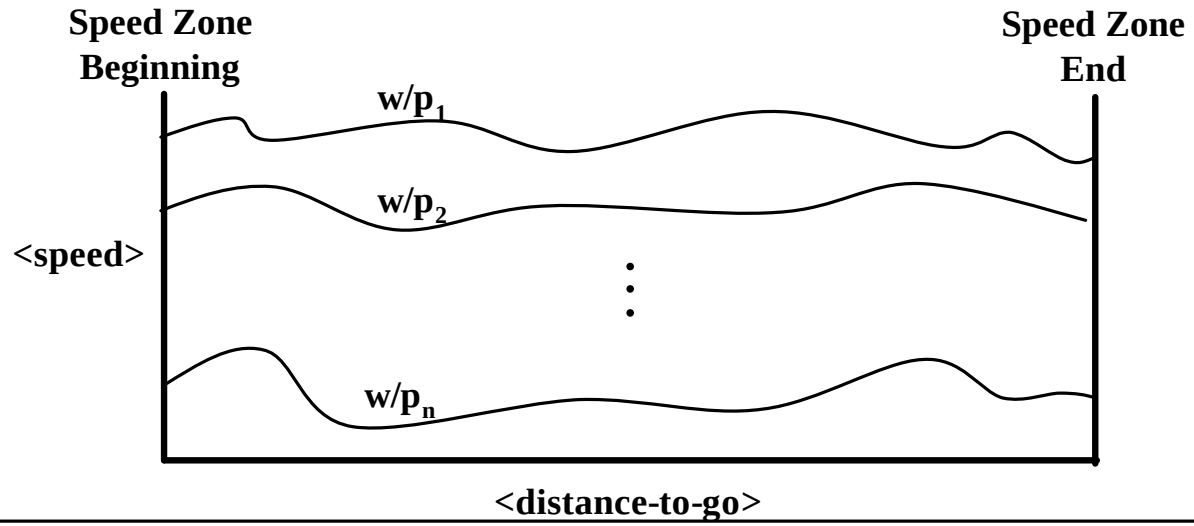
- Train Movement Model (TMM)
- Train Dynamic Model
- Object Model
- Agent Model
- Knowledge Based Blackboards
- Events Passed At Danger (EPAD)

Train Movement Model (TMM) Features

- TMM defines the train movement capabilities
  - Scheduling by the Dispatcher
  - Meet/pass conflict resolution
  - Route Locking
  - Train Dynamic Movement Model integrated with Human-factors
  - Consist speed dynamics and work equipment movement integrated
- Train departure randomization
  - Arbitrary (e.g. 7 day) train movement cycle
  - Departure times randomized
  - Randomization over multiple year/multiple mileage horizon for V&V
- Signal control logic defined by Boolean equations
  - Function of track occupancy
  - Function of train routing
  - Prevent dispatcher from assigning conflicting routes
  - Define block delays

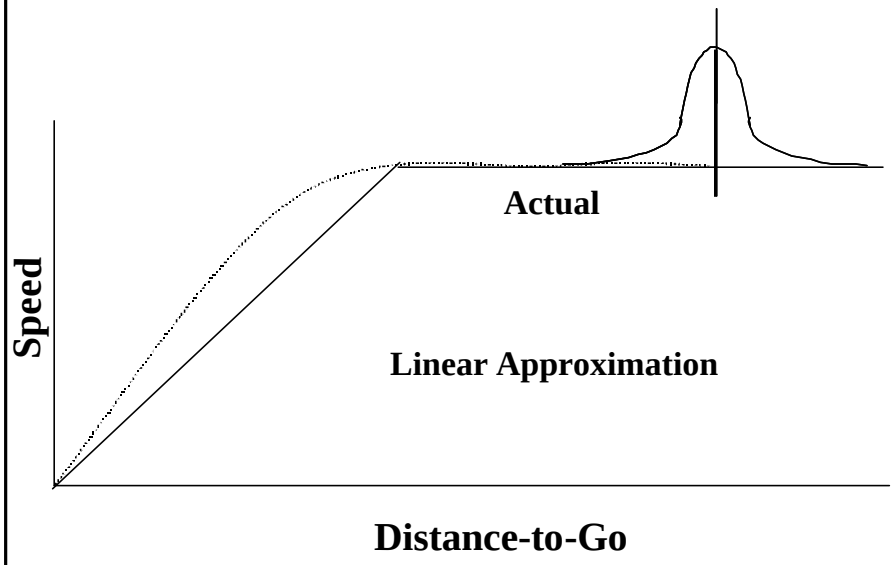
Average Speed Polynomial Model

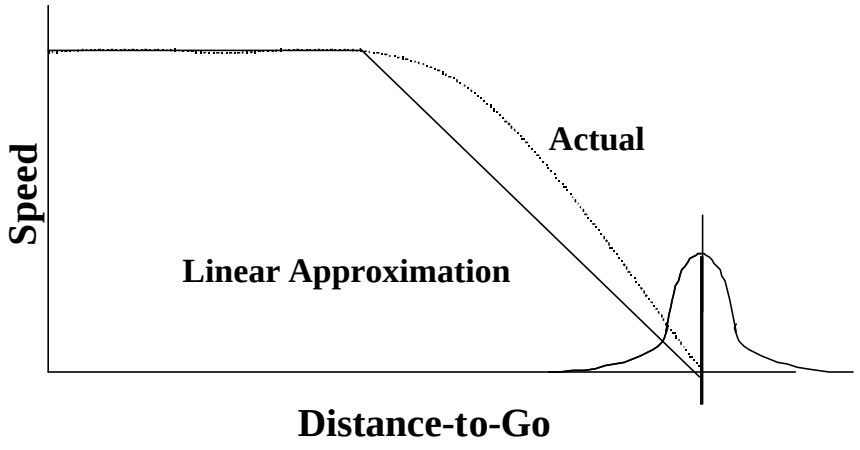
- Applied in regions where the train does not need to stop or accelerate
  - 3rd order polynomial: <speed> = $a(w/p)^3 + b(w/p)^2 + C(w/p) + d$
    - Davis Equation
    - Gravity forces
    - Curves forces
    - Traction effort
    - Human-factors target speed for speed zone



Linear Acceleration/Deceleration Model

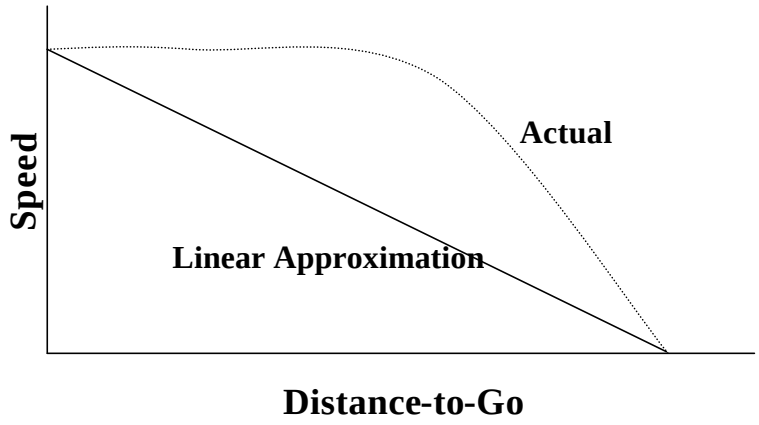
- Applied in regions where the train does needs to stop or accelerate & a condition satisfying a mishap-pair realization is not met
  - Provides a linear approximation of a train's physical behavior
  - Computationally less intensive

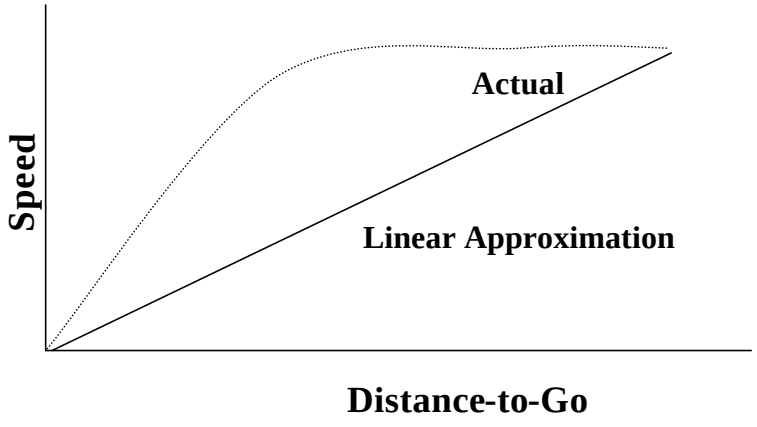




Dynamic Movement Model

- Stopping/acceleration required for Incident/Accident-pair realization
  - Train-to-train
    - Head-on
    - Rear-end
    - Raking
    - Siding
  - Train-to-Roadway Workers
  - Train-to-misaligned switch
  - Over speed





Object Model Features

- Captures object safety-critical appliance behavior
  - Incorporates transient behaviors
  - Incorporates improper repair effects
- Safety-Critical object model parameters
  - Failure hardware rate (includes effects of transient & permanent)
  - Hardware/software integrated Coverage
  - Repair
  - Human repair coverage

Object Model Features

- Operational state behavior
  - Appliance functioning as intended for given application
- State transition
  - Fault occurrence
    - Covered: fault is detectable -> Failed –Safe state
    - Uncovered: fault in not detectable -> Failed-Unsafe stats

Object Model Features

- Failed-safe state behavior
  - A known appliance failure that does not impact system safety
- State transitions
  - Repair
    - Correct repair -> Operational state
    - Incorrect repair -> Failed-Unsafe state
  - Transient recovery

Object Model Features

- Failed-unsafe state behavior
  - An unknown appliance failure that may or may not impact system safety
- State transitions
  - Maintenance
    - Correct maintenance -> Operational state
    - Incorrect maintenance -> Failed-Unsafe state
  - Transient recovery
  - Additional fault occurrence

Object Models – IDOT Base Case

- On-Board
  - Locomotive Inductive Pickup
  - MICROCAB Automatic Train Protection (ATP)
  - 4-aspect Cab Signaling Display
  - Penalty Brake Valve Interface
  - Penalty Brake Valve (P2A)
- Track
  - MICROTRAX
  - Broken Rail
  - Switch
- Wayside
  - Permanent Speed Sign
  - Signals
    - Control Point
    - Intermediate
  - MICROLOK
  - Flags

Agent Model Applications

- Golden (Compliant) Agent behavior taken from UPRR operating rules
- Agent model supports:
  - Train crew
  - Dispatcher
  - Roadway Workers

Agent Model Behavior

- Actions categorized into three (3) behavioral states
  - Correct Action (Compliant to the Operational Rulebook)
  - Erroneous Action (Non-Compliant to the Operational Rulebook)
  - Non-Responsive
- Behavioral path selection influenced by defined probabilistic behaviors
  - Recognition
  - Interpretation
  - Coverage
  - Compliance
- Behavioral probabilities currently modeled as constants

Train Crew

- Engineer and conductor modeled as a single entity
  - Each train has its own unique train crew
- Voice requests are agreed to by both engineer & conductor
  - EIC
  - Dispatcher
    - Report appliance failures
    - Request authority at Control Point signals
    - Resolve conflicts with flags

Dispatcher

- Single dispatcher control IDOT PTC territory
- Dispatcher provides voice command in times of detected signal failure
  - Golden instructions identical to that entered in CAD
  - Instructions can be corrupted by dispatcher
- Dispatcher create work zones & temporary speed restrictions due to reported equipment failures
  - Form A
    - 75% require flagging
  - Form B
    - Major track infrastructure work
    - 25% of track work
  - Track and time
    - Set Control Point signals RED to protect work area
    - 75% of track work
  - Create overlapping work zones
  - Improperly revoke work zone & temporary speed restrictions limits

Roadway Workers

- Voice control provided by EIC
  - Single EIC controls the work zone
  - EIC may set restricted speed limit too high
- Form B work zones marked by flags
  - Flags may be missing
  - Inappropriately displayed
    - Wrong location
    - Wrong type
- Track & time based work zones marked by RED Control Point signals
  - Joint authority
- Workers may work outside assigned work zone

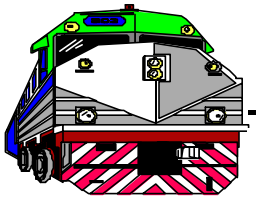
Knowledge Based Blackboard Partitioning

- Agent-to-Object
  - Object behavior table
    - Identifies stimulus associated with a particular object state
  - Agent behavior table
    - Identifies train movement modalities associated with a particular agent state
  - EPAD determination table
    - Identifies which actions create an EPAD
- Agent-to-Agent
  - Agent behavior table
    - Identifies agent actions relative to an agent based stimulus
    - Provides a series of “handshaking” between agents
      - Ability of one agent to cover another agents mistake
  - EPAD determination table
    - Identifies which actions create an EPAD

EPAD Conditions

- Train-to-Train
  - Head-on
  - Rear-end
  - Raking
  - Side
- Train-to-track
  - Broken rail
  - Switch alignment
  - Over-speed
    - Spiral track
    - Tangent track
    - Switch
  - Emergency braking
- Train to Roadway Workers and Work Zone
- Work Equipment to Work Equipment

EPAD Log Illustration



IDOT LOGS:

ASCAP Event Passed At Danger (EPAD) Log

	Simulation ID unique to experiment	Base Case 2, Seed 2	
	EPAD Type	Broken rail	
	EPAD Date calendar date	1312	
	EPAD Time military time	9:48:47	
	Accumulated Train Miles	1163909.9	

Locomotive and Crew Identification

	Train ID	9	
	Cab Equipment	NO	
	Crew ID	9	
	Hours on Shift	0.35	hours

EPAD Quantified Dynamic Movement Vector

1	Locomotive Position	96.8	milepost number
2	Locomotive Acceleration	0.9	ft/s2
3	Locomotive Velocity	60	miles/hour
4	Locomotive Target Speed	60	miles/hour
5	Locomotive Direction of Travel	North	
6	Number of Locomotives	2	
7	Locomotive Horsepower	884.6	HP
8	Locomotive Momentum	2429.1	ton-ft/s
9	Average % Grade	0	
10	Curvature	0	degrees/100 ft
11	Line-of-Sight Distance	1640	ft
12	Train Consist Type	Freight	
13	Train Length	0.26	miles
14	Number of Cars	27	
15	Average Car Weight	55	tons
16	Locomotive Efficiency	0.81	%
17	Object Type	Broken Rail	
18	Object State	Fail Safe	
19a.	Work Zone Locations beginning MP	N/A	
19b.	Work Zone Locations end MP	N/A	
19ab.1.	Work Zone Locations beginningMP and end MP Equipment	N/A	

EPAD Log Illustration

20	Agent Behaviors		
20.1.	Dispatcher State	Continue	
20.2.	Dispatcher Action		
20.3.	Train Crew State	Compliant to Actual Stimulus	
20.4.	Train Crew Action	Proceed at posted speed	
20.5.	Maintenance-of-Way Worker State	Continue	
20.6.	Maintenance-of-Way Worker Action		
21	Blackboard Outcome	Train intersected a broken rail	
22	Likelihood of Occurrence	0.00017	

EPAD Qualitative Dynamic Movement Vector

1	Dispatcher equipment reliability	N/A	%
2	Dynamic Braking Available	YES	Yes/No
3	On-board equipment reliability	N/A	%
4	Wayside equipment reliability	N/A	%
5	Communications equipment reliability	N/A	%
6	Dispatcher Experience	N/A	Years
7	Train Crew Experience	[illegible]	Years
8	Special Bulletins	CTC	Yes/No
9	Territory Type (DTC, TCS, CTC, PTC, CBTC)	TCS	
10	Track Conditions	Good	Good, Bad, Poor
11	Weather	Good	Good, Bad, Poor
12	Visibility	Good	Good, Bad, Poor

1 **EPAD Resulted in a Mishap**

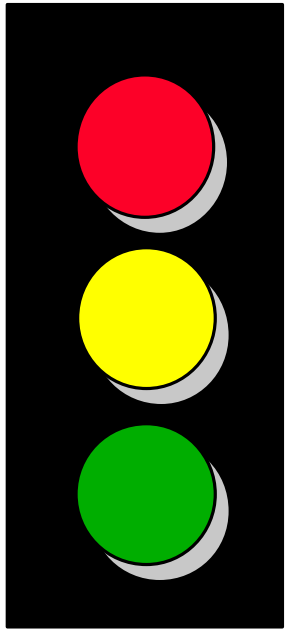
1a.	Mishap Type	BrokenRail	
1b.	Incident or Accident?	Accident	
1b.i.	Secondary Train ID		
1b.ii.	TertiaryTrainID	N/A	
	Mean	$139,385.67	Dollars
	Lower Bound	$4,759.61	Dollars
	Upper Bound	$4,081,928.07	Dollars

IDOT EPAD LOG rev 1

Page 1 of 1
Simulation Generation Date: 12/04/02

3-Lamp Control Point Signal

- Single signal head
  - Three (3) lamps
    - Red
    - Yellow
    - Green
  - Five (5) permissible aspects
    - Red
    - Flashing Red
    - Yellow
    - Flashing Yellow
    - Green



Object Model Data: 3-Lamp Control Point Signal

Simulation Level	Failure Rate (λ) failures/hr	Coverage (*C*)	Travel Time hours	Repair Rate (μ) repairs/hr	Repair time hours	Human Repair Coverage (δ)
Validation Case 1	1/20,000 = 0.00005	0.9	2	1/8 = 0.125	10	0.9999505
Validation Case 2	1/20,000 = 0.00005	0.9	2	1/8 = 0.125	10	0.9999505
Base Case	1/20,000 = 0.00005	0.9	2	1/8 = 0.125	10	0.9999505

Object Behavior Table : 3-Lamp Control Point Signal

Golden Stimulus	Object State		
	Operational	Failed Safe	Failed Unsafe
Red	Red	Dark	Flashing Red
			Yellow
			Flashing Yellow
			Green
			Flashing Green
			Green & Yellow
			Flashing Green & Yellow
			Green & Flashing Yellow
			Flashing Green & Flashing Yellow
			Green & Red
			Flashing Green & Red
			Green & Flashing Red
			Flashing Green & Flashing Red

Object Behavior Table: 3-Lamp Control Point Signal

Golden Stimulus	Object State		
	Operational	Failed Safe	Failed Unsafe
Red	Red	Dark	Yellow & Red
			Flashing Yellow & Red
			Yellow & Flashing Red
			Flashing Yellow & Flashing Red
			Green & Yellow & Red
			Flashing Green & Yellow & Red
			Green & Flashing Yellow & Red
			Green & Yellow & Flashing Red
			Flashing Green & Flashing Yellow & Red
			Flashing Green & Yellow & Flashing Red
			Green & Flashing Yellow & Flashing Red
			Flashing Green & Flashing Yellow & Flashing Red

Object Behavior Table: 3-Lamp Control Point Signal

Golden Stimulus	Object State		
	Operational	Failed Safe	Failed Unsafe
Flashing Red	Flashing Red	Dark	See Red for enumerated list
Yellow	Yellow	Flashing Red Dark	See Red for enumerated list
Flashing Yellow	Flashing Yellow	Flashing Red Dark	See Red for enumerated list
Green	Green	Flashing Yellow Dark	See Red for enumerated list

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Dark (or any aspect display that is not defined by the object's operational or failed-safe behavioral state)	GCOR 5.15: If a signal is improperly displayed, or a signal, flag or sign is absent from the place it is usually shown, regard the signal as showing the most restrictive indication it can give. GCOR 9.4: Improperly displayed signals or absent lights – If a light is absent or a white light is displayed where a colored or lunar light should be, regard a block or interlocking signal as displaying the most restrictive indication it can give. UPRR Special Instruction 9.2.14: Stop before any part of train or engine passes the signal. Wait for signal change or dispatcher instructions.	Increase speed within a range from posted permanent speed to maximum speed attainable by locomotive Decrease speed within a range from zero to posted permanent speed Apply full service braking (train or engine passes the signal) Apply emergency braking	Continue train movement at current speed

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Red	UPRR Special Instruction 9.2.14: Stop before any part of train or engine passes the signal. Wait for signal change or dispatcher instructions.	Increase speed within a range from restricted speed, not exceeding prescribed speed, to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to restricted speed, not exceeding prescribed speed	
		Apply full service braking (train or engine passes the signal)	
		Apply emergency braking	

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Flashing Red	UPRR Special Instruction 9.2.12: Proceed at restricted speed, not exceeding prescribed speed, through turnout.	Increase speed within a range from restricted speed, not exceeding prescribed speed, to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to restricted speed, not exceeding prescribed speed	
	If train within visual look-ahead range, then apply braking (either full service or emergency depending on operational conditions)	Apply full service braking	
		Apply emergency braking	

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Yellow	UPRR Special Instruction 9.2.5: Proceed prepared to stop before any part of train or engine passes the next signal. Freight trains exceeding 30 MPH must immediately reduce to 30 MPH. Passenger trains exceeding 45 MPH must immediately reduce to 45 MPH.	Increase speed within a range from 30 MPH for freight and 45 MPH for passenger to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to 30 MPH for freight and 45 MPH for passenger trains	
	If train within visual look-ahead range, then apply braking (either full service or emergency depending on operational conditions)	Apply full service braking	
		Apply emergency braking	

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Flashing Yellow	UPRR Special Instructions 9.2.3: Proceed prepared to stop at second signal. Freight trains exceeding 40 MPH must immediately reduce to 40 MPH. Passenger trains may proceed but must not exceed 40 MPH passing next signal.	Increase speed within a range from 40 MPH to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to 40 MPH	
	If train within visual look-ahead range, then apply braking (either full service or emergency depending on operational conditions)	Apply full service braking	
		Apply emergency braking	

Agent Behavior Table: 3-Lamp Control Point Signal

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Green	UPRR Special Instruction 9.2.1: Proceed at posted speed.	Increase speed within a range from posted speed to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to posted speed	
	If train within visual look-ahead range, then apply braking (either full service or emergency depending on operational conditions)	Apply full service braking	
		Apply emergency braking	

3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Dark (or any aspect display that is not defined by the object's operational or failed-safe behavioral state)	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied

3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Red	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD EPAD Incident/Accident occurs if over speed, work zone, broken rail or train-to-train Incident/Accident pair criteria is satisfied

3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Flashing Red	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD if Train Speed in excess of restricted/prescribed speed EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied

3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Yellow	Safe Train Movement	Safe Train Movement	EPAD	Safe Train Movement	EPAD Incident/Accident	EPAD if Train Speed in excess of from 30 MPH for freight and 45 MPH for passenger trains
			EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied			EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied

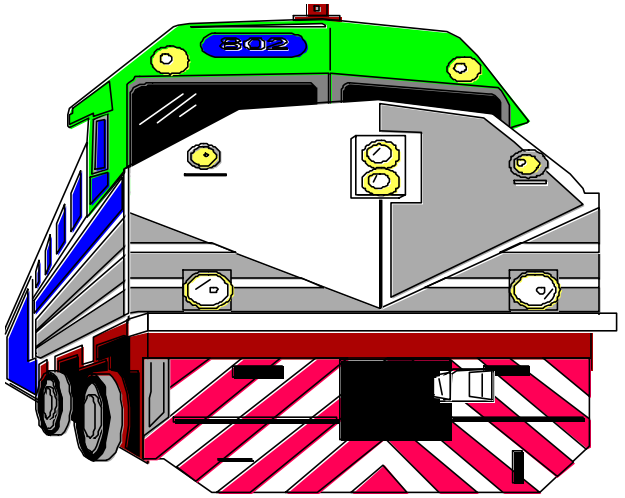
3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Flashing Yellow	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD if train speed in excess of 40 MPH EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied

3-Lamp Control Point Signal – EPAD Table

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Green	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD if train speed in excess of posted speed EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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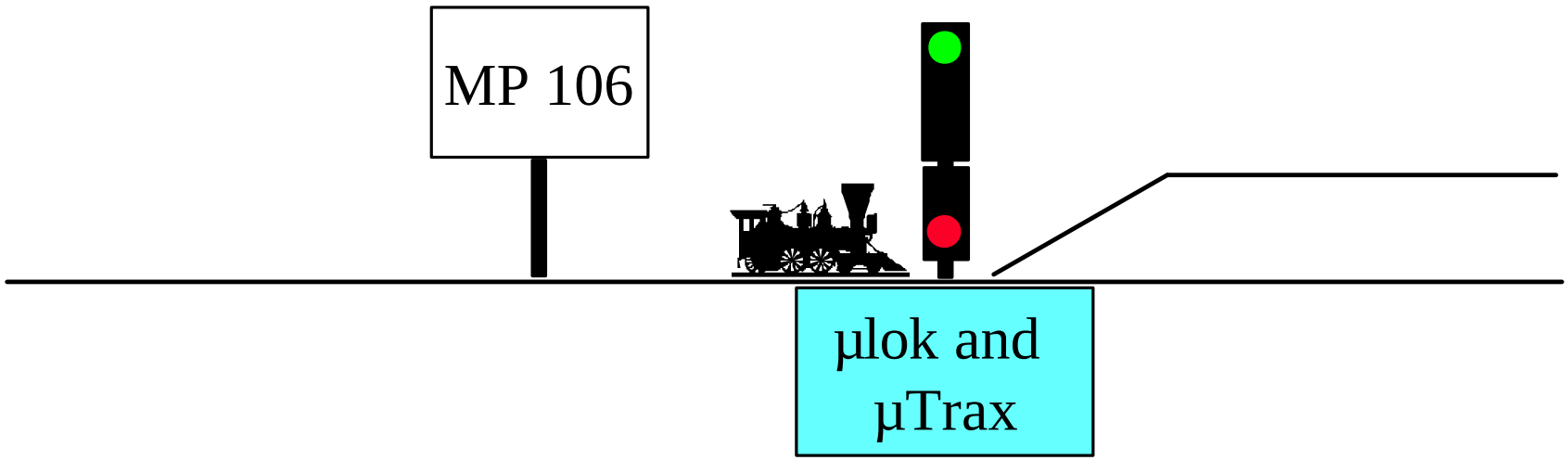
Knowledge – Based Blackboards

Dr. Lori M. Kaufman

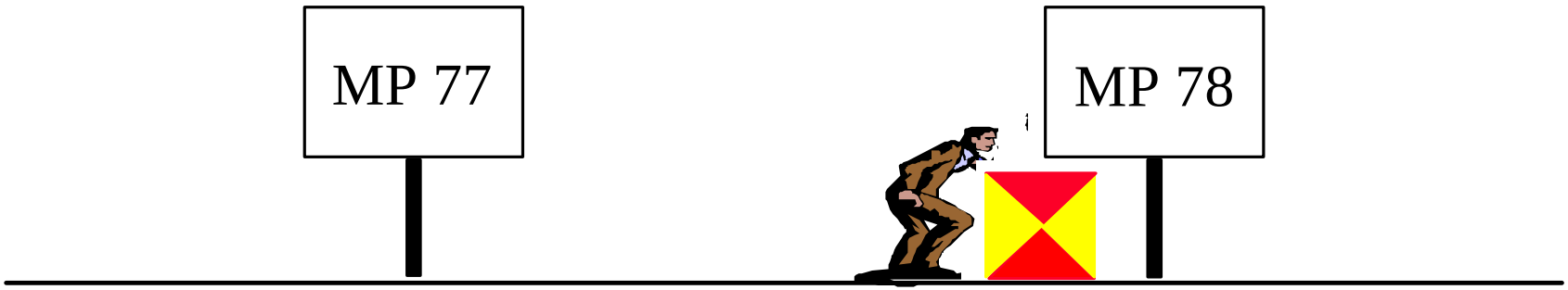
AMTK 303 – Control Point at Ballard

- Object Behavioral State: Operational



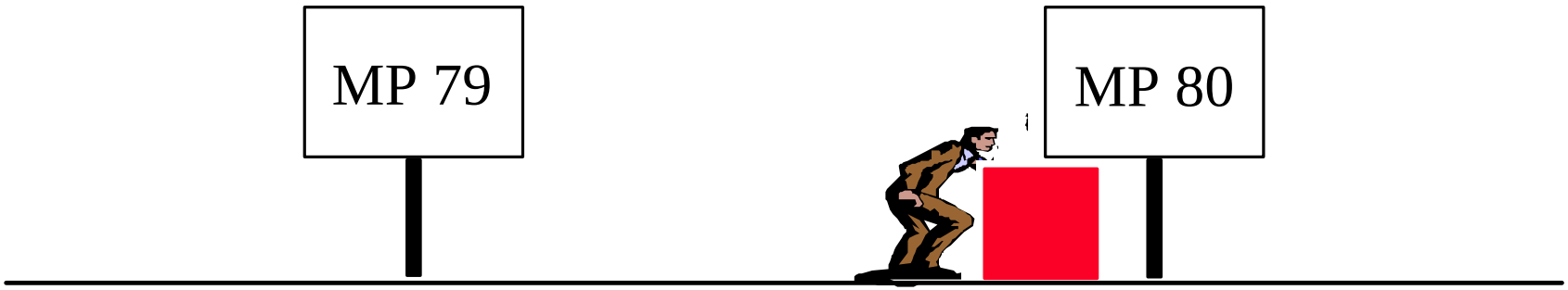
Yellow/Red Flag Placement

- Work zone located at MP 80
- Flagging to be used



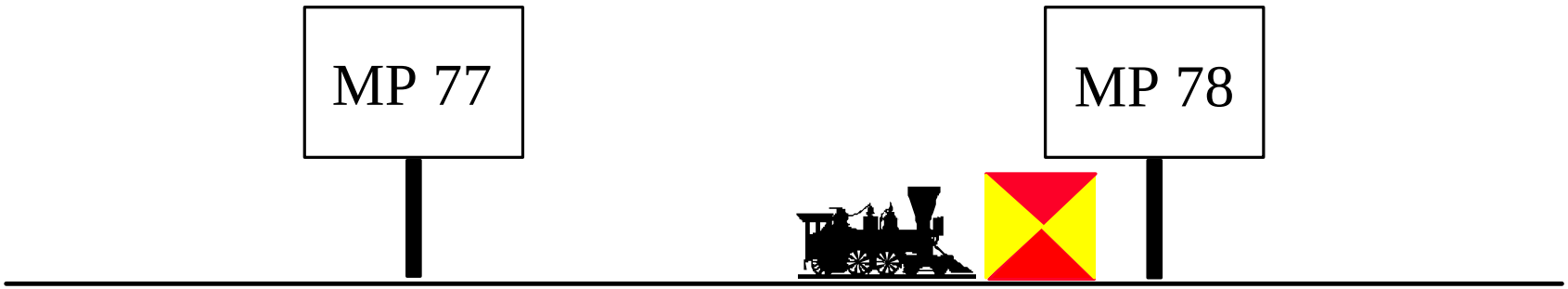
Red Flag Placement

- Work zone located at MP 80
- Flagging to be used



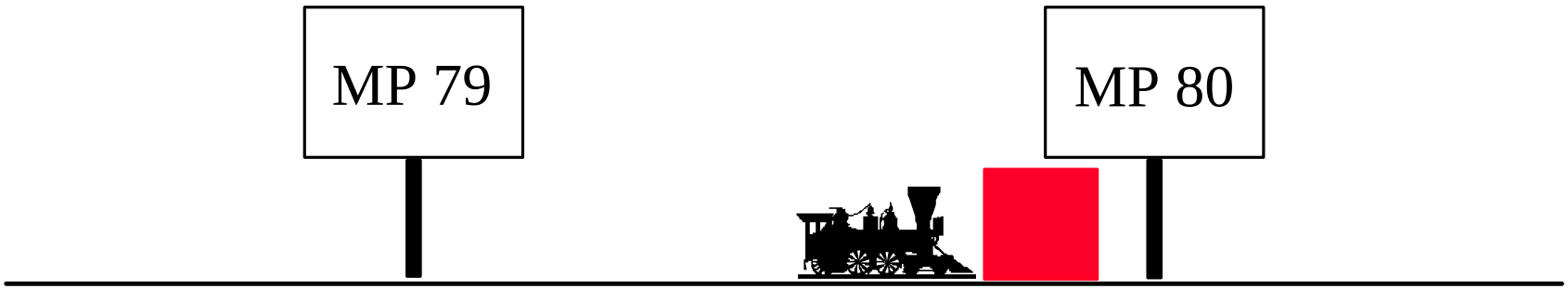
AMTK 303 – Approaching a Yellow/Red Flag

- Train crew provided Form B
  - Work zone located at MP 80
  - Flagging to be used



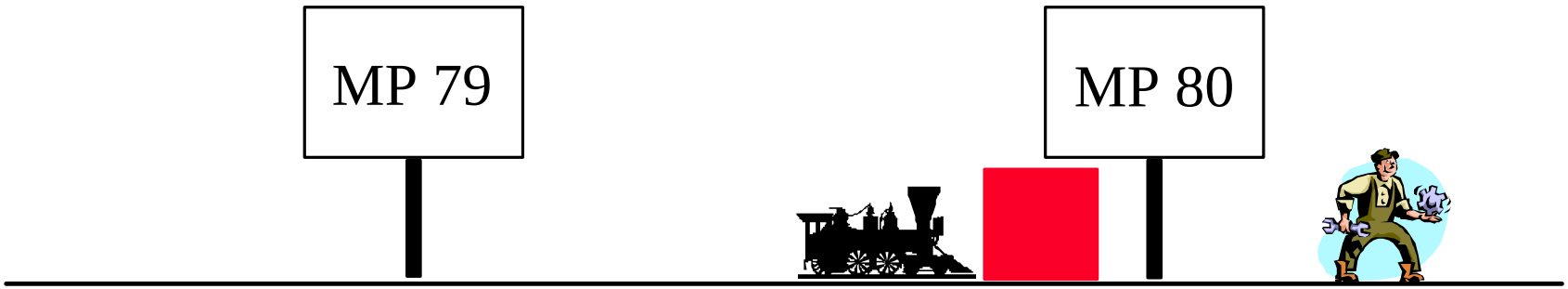
AMTK 303 – Approaching a Red Flag

- Work zone located at MP 80
- Flagging to be used

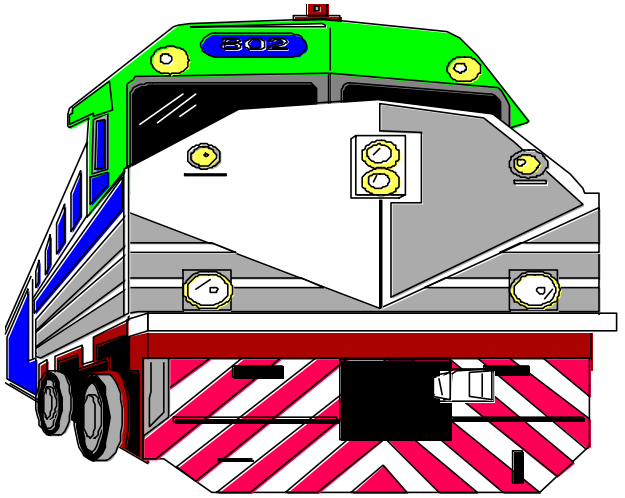


AMTK 303 – Contacting EIC

- Work zone located at MP 80
- Flagging to be used



A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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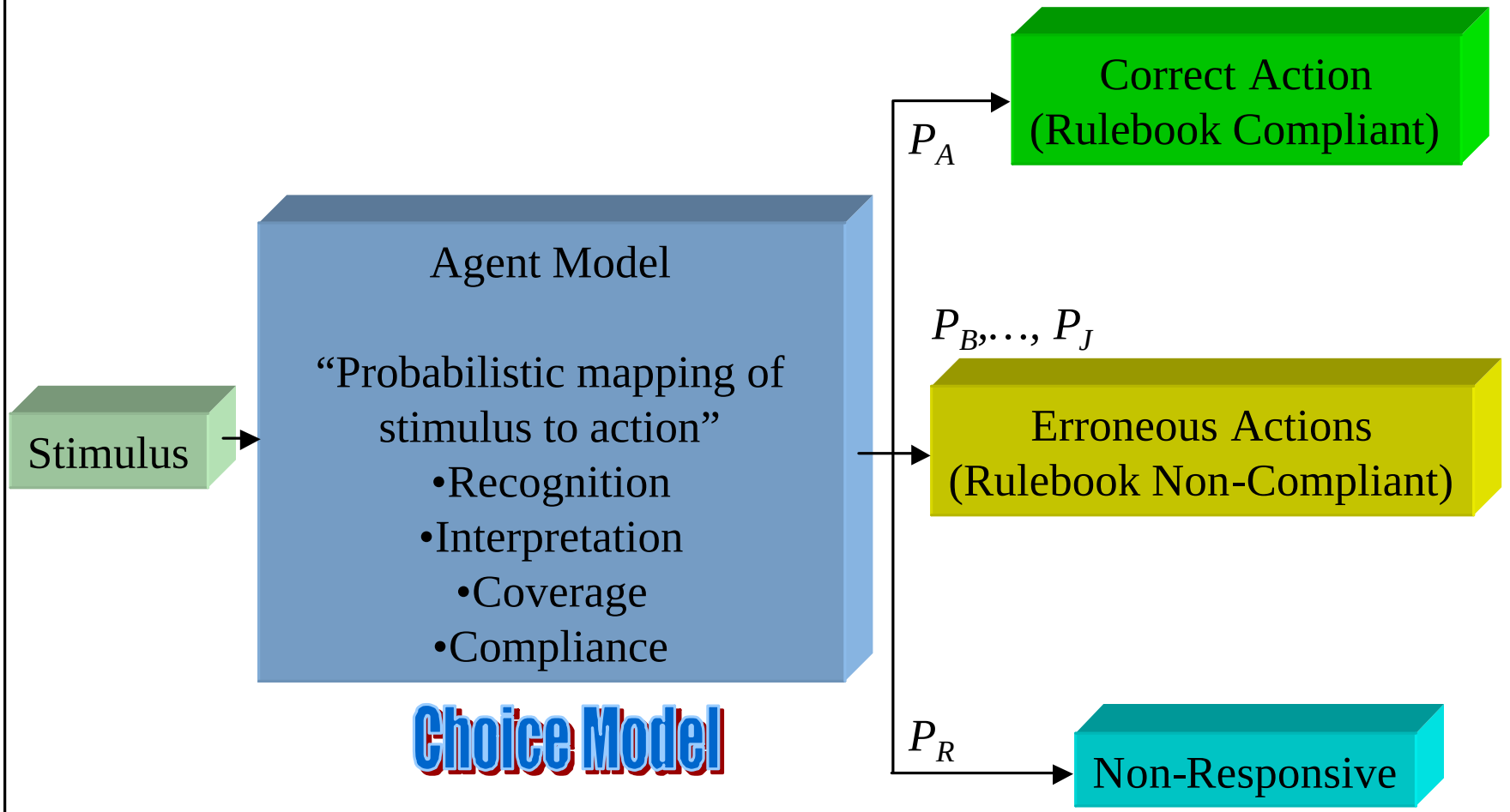
Choice Model Knowledge-Based Blackboards

Dr. Donald E. Brown

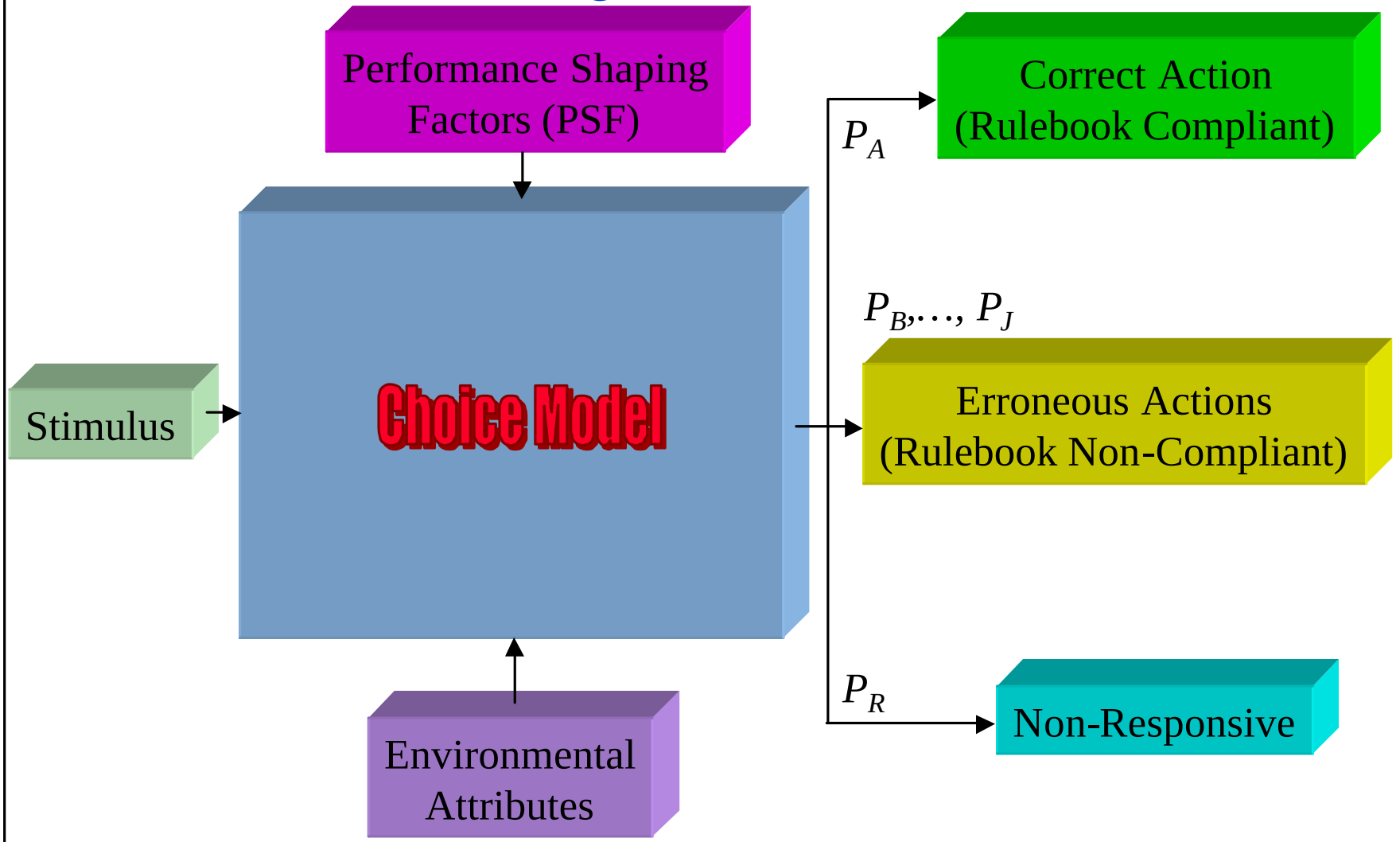
Agent Model


Correct Action
(Rulebook Compliant)
P_A
Agent Model
"Probabilistic mapping of stimulus to action"
•Recognition
•Interpretation
•Coverage
•Compliance
Stimulus
$P_B, \ldots, P_J$
Erroneous Actions
(Rulebook Non-Compliant)
Choice Model
P_R
Non-Responsive

Definitions

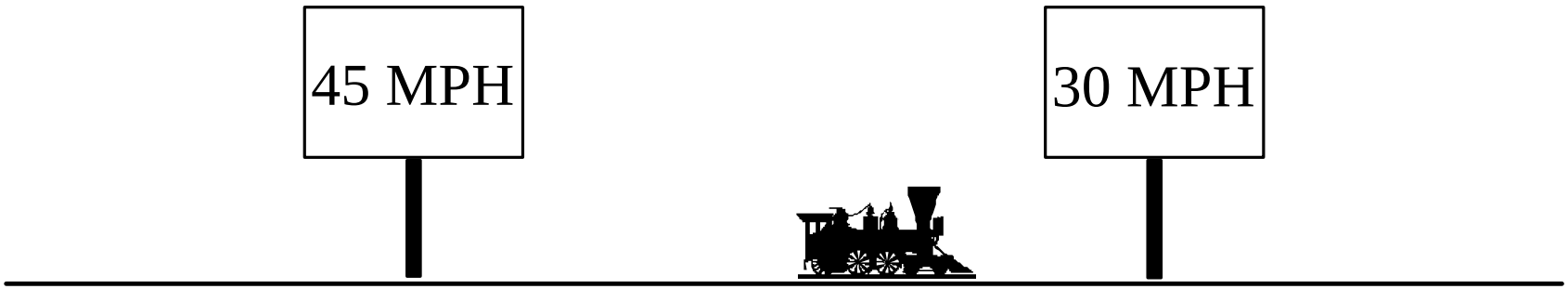
- Choice Model
- Environment
- Environmental Attributes
- Performance Shaping Factors
- Stimulus
- Utility Function

Agent Model

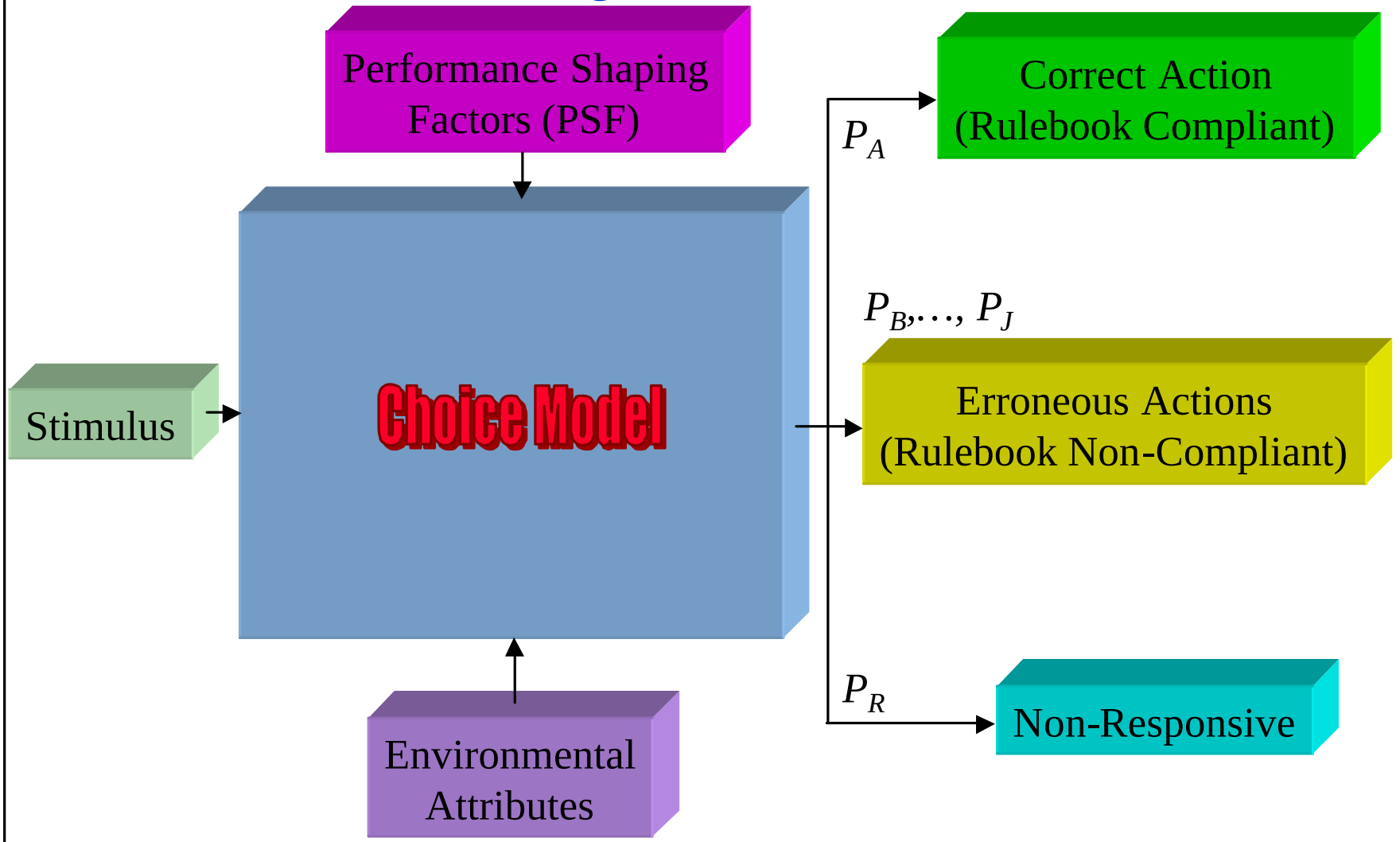

Performance Shaping Factors (PSF)
Correct Action (Rulebook Compliant)
P_A
$P_B, \ldots, P_J$
Stimulus
Choice Model
Erroneous Actions (Rulebook Non-Compliant)
P_R
Non-Responsive
Environmental Attributes

Choice Model Example Application

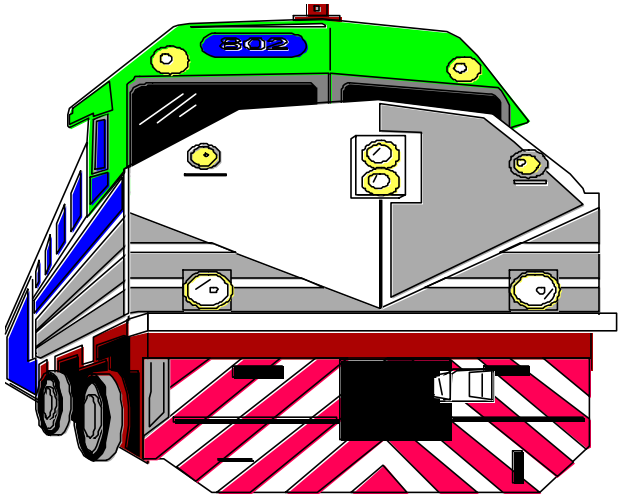
- Train crew with average experience encounters a change in permanent speed restriction



Agent Model


Performance Shaping Factors (PSF)
Correct Action (Rulebook Compliant)
P_A
$P_B, \ldots, P_J$
Stimulus
Choice Model
Erroneous Actions (Rulebook Non-Compliant)
P_R
Non-Responsive
Environmental Attributes

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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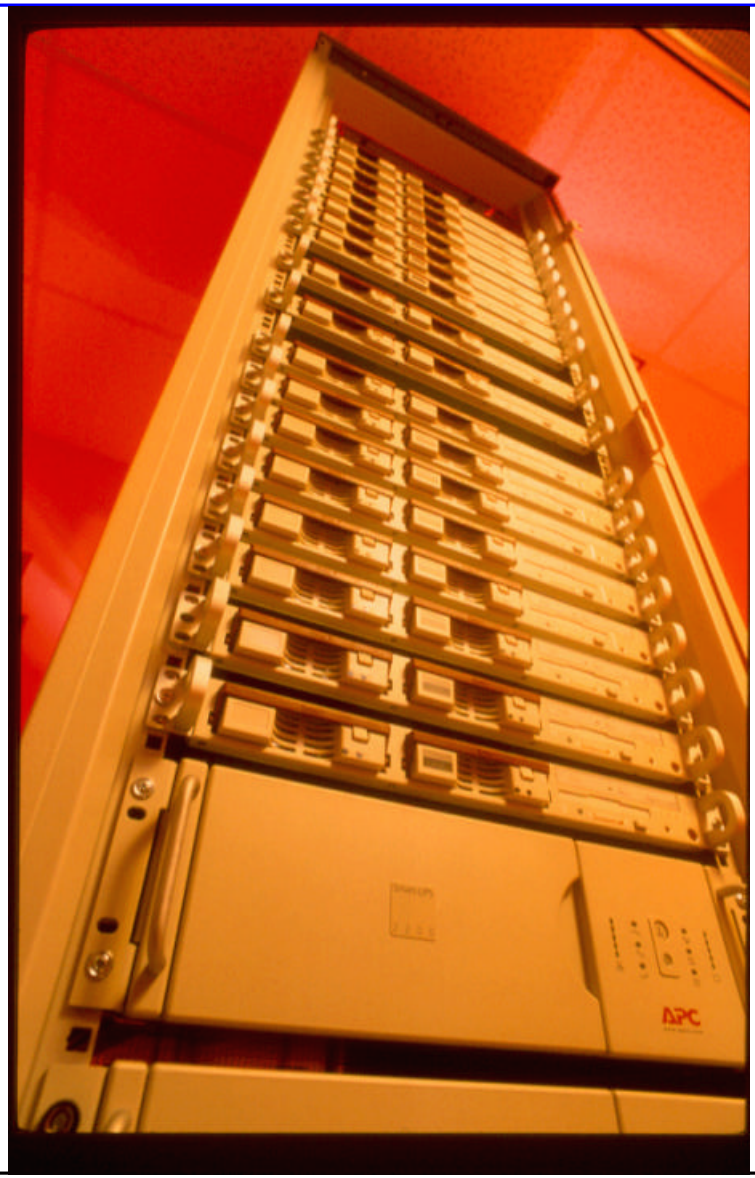
The Rail Analysis Cluster

Parallel Simulation

- The Rail Analysis Cluster (TRAC) currently contains 18 dual-processor computers.
- 16 of these computers are used as “compute nodes”
- 1 of these computers is used as the controller and coordination point for the 16 compute nodes
- 1 of these computers is used as an “interface node” running a secure web server



Parallel Simulation

- Simulation in parallel is trivial if the parallel programs do not need to communicate
  - This is the typical situation for many of our simulations
- Many of the rail simulations are for "what if" analysis – the same simulation must be run multiple times with slightly different parameters
  - This problem is very efficient on the cluster because the simulations are basically independent
- We would like to run very long simulations, and we are examining the feasibility for multiple independent shorter simulations to represent a single longer simulation
  - We have not yet determined the validity of this approach, but it would permit rapid completion of extensive simulations

The Web-Based Simulator Interface

- Normal access to the simulator is through a secure web server
- This permits simulator control from any machine with a web browser
- This provides clear distinction between the software development interface and the application use interface
- This is now used for simulations by the UVA researchers
- The same functionality exists anywhere in the world where internet access is available

Reaching the Simulator

- Researchers at UVA connect directly to the *secure* web server on the cluster
- This secure web server is linked to the public web pages of the Center
  - http://www.ece.virginia.edu/trainsafety
- A secure web server is used to
  - Limit simulator access to authorized users
  - Support access limitations based upon user authorities
  - Provide encryption of all communication between the browser and the server
- Start from the Center's public web site…
  - Note that the screen view is taken directly from the Center's public web site
  - This is currently accessible over the web from anywhere in the world

Choosing Simulation

- When the simulation choice is made on the home page, the browser is redirected to a different site
- The destination site is a secure web server on the cluster computer
- Before the user can proceed to access the secure server, it is necessary to identify and authenticate the user
- This is accomplished using the standard login page
  - Note that the login page was produced by the secure server currently running on the cluster

Application Choices

- Once the user has passed the challenge, the secure web site becomes available
- Currently, a few options are available to the user
  - Start a new simulation
  - Edit stored parameters
  - Review the results of completed simulations
  - Log off of the cluster application
- To start a new simulation, just click the start simulation button
- Before leaving this page, note that the browser is assuring the user that this is a secure web site
  - Note that this choice page was produced by the secure server currently running on the cluster

Choosing A Specific Simulation

- To start a simulation, the user must select the specific simulation to be run
- Each user has a user-specific set of simulations that the particular user can run
  - A “MAGLEV” user might have only “MAGLEV” simulations
  - An individual working on a specific railroad simulation might have access only to simulations for that railroad
- After choosing to start a simulation, the user is presented with a list of simulations available to that specific user
- The user highlights the desired application and clicks the “start application” button
  - Note that this menu page was produced by the secure server currently running on the cluster

Setting Simulation Parameters

- When a simulation has been selected, its parameters must be set
  - The same simulation application can behave very differently for different parameter sets
- Parameter files can be prepared on the local computer and uploaded over the secure web link
  - Multiple parameter files can be stored on the server or one can be uploaded only for one simulation set
- At this point, a parameter file must be selected, or a set of default parameters can be used
- Large simulations can require significant time, so it can also be useful to assign a meaningful name to this simulation – This task is performed here
  - Note that this parameter page was produced by the secure server currently running on the cluster

Job Submission and Completion

- After the application is chosen, its parameters are set, and a name is assigned, the job is submitted to the cluster by clicking the “run” button
- The submission is confirmed by another web page that also offers the option the view the results.
- Clicking on the “Retrieve My Results” button directs the user to another page where the simulation results can be obtained
  - Note that this acknowledgement page was produced by the secure server currently running on the cluster

Retrieving Results

- Choosing to retrieve results cannot yield results for simulations not yet complete, but results from earlier simulations may be available
- Note that UVA users currently retrieve results manually, but the web server is being enhanced to provide these results directly through the web server
  - The remaining slides illustrate how this might appear
- The results page will provide a list of the jobs submitted by the specific user
  - This list will include the job names assigned by the user, the time of submission, and the job status as running or completed.
  - This list also includes the option to delete the results of a job to manage clutter or to remove the results from the cluster for any other reasons
- Here, the red dot under results indicates that the results are not yet ready – Green indicates ready

Viewing Results

- When the results become available, the results indicator turns green
- Clicking on a green results indicator takes the user to another page that offers a selection of result graphics
- Choosing one of these graphics yields other pages that provide data in graphical form for review
  - An illustrative example might give a choice from among several days of string charts and an Incident/Accident graph

A String Chart Window

- Choosing one of the string charts might pop up another browser window containing the requested chart
  - Note that this is an illustration – these charts are currently produced by the simulations, but they are not yet available in this web format

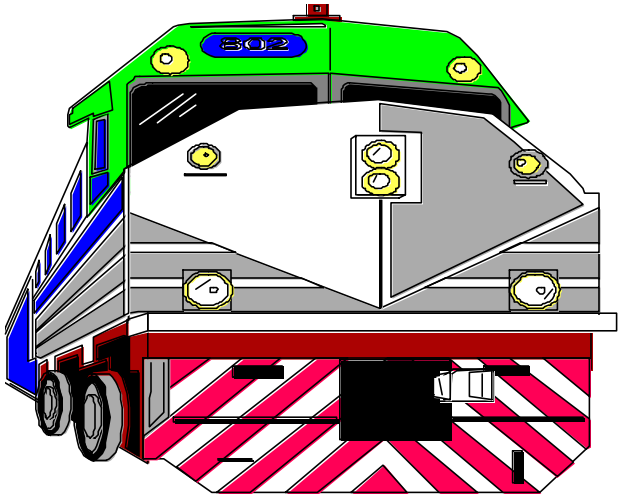
Viewing Another Graphic

- Another choice offered is the Incident/Accident Count graph. Clicking this button might pop up another window to provide this graph.
  - Note that this is an illustration – these charts are currently produced by the simulation process, but they are not yet available in this web format

Operational Interface

- The result of this approach is a convenient and portable interface that provides access to cluster computation using only readily available standard web browsing tools
- The interface is intuitive and familiar to anyone who already uses the web
- Security is provided by the same mechanisms that secure electronic commerce applications
- Most of the interactions between the browser and the cluster require only limited information interchange so that analyses could be completed on a laptop with a modem from anywhere in the world
- This is the interface that we are starting to use for our simulations at UVA

Group Comments and Discussion



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ASCAP Tutorial Summary

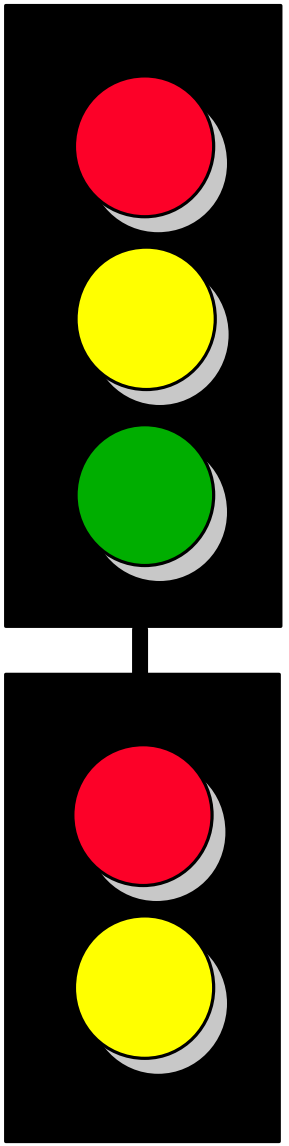
- ASCAP Peer Review Process Underway to establish Methodology Adequacy and IDOT Calibration
- First Peer Review Session with Labor Completed
- ASCAP is RSAC compliant – To be Determined by FRA
- Parallel Processing makes Billion Mile Experiments Possible
- ASCAP Enhancements:
  - WEB-based UVA USER INTERFACE
  - Knowledge-based Black Board Choice Model
  - Continued Formalized Validation and Verification

Knowledge – Based Blackboards

Dr. Lori M. Kaufman

5-Lamp Control Point Signal

- Single signal head
  - Top Head - Three (3) lamps
    - Red
    - Yellow
    - Green
  - Bottom Head – Two (2) lamps
    - Red
    - Yellow
  - Seven (7) permissible aspects
    - Red over Red
    - Flashing Red over Red
    - Red over Yellow
    - Red over Flashing Red
    - Flashing Yellow over Red
    - Green over Red



Knowledge Based Blackboard – Train Crew Response

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Green/Red	UPRR Special Instruction 9.2.1: Proceed at posted speed.	Increase speed within a range from posted speed to maximum speed attainable by train	Continue train movement at current speed
	If train within visual look-ahead range, then apply braking (either full service or emergency depending on operational conditions)	Decrease speed within a range from zero to posted speed	
		Apply full service braking	
		Apply emergency braking	

Knowledge Based Blackboard – Train Crew Response

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Green/Red	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD if train speed in excess of posted speed EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied

Work Zone Modeling for Areas Where Flagging May Be Used

- Written notification
  - Form A: temporary speed restrictions
  - Form B: work zone
  - Train crew provided advance knowledge of restricted zone location
  - Flagging not required
  - Flagging can serve as a reminder
    - Proper flag displayed at correct location
- Restricted areas may arise during travel
  - Train crew must be alert watching for flags

Knowledge Based Blackboard – Flag Placement

GCOR 5.4.1: Yellow-red flags will be used when a train may be required to stop

Roadway Worker Behavior		
Correct Action(Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
GCOR 5.4.3: Place a yellow-red flag two (2) miles before the restricted area.	Place red flag two (2) miles before the restricted area.	Place no flag
	Place yellow flag two (2) miles before the restricted area.	
	Place green flag two (2) miles before the restricted area.	
GCOR 5.4.3: If indicated by Form B, then place flag less than two (2) miles before the restricted area.	Place yellow flag at an incorrect location	
	Place red flag at an incorrect location	
	Place yellow/red flag at an incorrect location	
	Place green flag at an incorrect location	

Knowledge Based Blackboard – Flag Placement

GCOR 5.4.7: A red flag is displayed where trains must stop

Roadway Worker Behavior		
Correct Action(Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
GCOR 5.4.7: Place a red flag at the beginning boundary of the speed restricted area.	Place a green flag at the beginning boundary of the speed restricted area.	Place no flag
	Place a yellow/red flag at the beginning boundary of the speed restricted area.	
	Place a yellow flag at the beginning boundary of the speed restricted area	
	Place a yellow flag at an incorrect location	
	Place a red flag at an incorrect location	
	Place a yellow/red flag at an incorrect location	
	Place a green flag at an incorrect location	

Knowledge Based Blackboard – Train Crew Response

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Yellow/Red Flag	GCOR 5.4.3: Crew members must be prepared to stop short of a red flag in two (2) miles If no red flag is displayed, then 1. Stop prior to written location of restricted area 2. Contact EIC or dispatcher	Increase speed within a range from current to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to current	
		Apply full service braking	
		Apply emergency braking	

Knowledge Based Blackboard – Train Crew Response

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Yellow/Red Flag	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident occurs if over speed Incident/Accident pair criteria is satisfied	Safe Train Movement	EPAD Incident/Accident	EPAD if Train Speed too fast to allow for full service braking prior to Red flag EPAD Incident/Accident occurs if over speed or train-to-train Incident/Accident pair criteria is satisfied

Knowledge Based Blackboard – Train Crew Response

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance to Rule)	**Erroneous Action (Non-Compliance to Rule)**	**Non-Response**
Red Flag	GCOR 5.4.7: Train must stop short of red flag After stop, contact dispatcher	Increase speed within a range from current to maximum speed attainable by train	Continue train movement at current speed
		Decrease speed within a range from zero to current	
		Apply full service braking	
		Apply emergency braking	

Knowledge Based Blackboard – Train Crew Response

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	**Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)**	**Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR**	**Apply Full Service Braking**	**Apply Emergency Braking**	**Continue train movement at current speed**
Red Flag	Safe Train Movement	EPAD Incident/Accident Work Zone incursion	EPAD Incident/Accident Work Zone incursion	Safe Train Movement	EPAD Incident/Accident	EPAD Incident/Accident Work Zone incursion

Knowledge Based Blackboard – Train Crew Query

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance To Rule)	**Erroneous Action (Non-Compliance Rule)**	**Non-Response**
Voice Control Active	GCOR ? Request block authority for the correct block	Request block authority for a random block*	Does nothing

Knowledge Based Blackboard – EIC Response

Actual Stimulus	Dispatcher/EIC Behavior		
	Correct Action (Compliance To Rule)	**Erroneous Action (Non-Compliance Rule)**	**Non-Response**
Train Crew requested block authority for the correct block	GCOR ?: Grant authority if requested block available; Deny authority if block unavailable	Grant authority if requested block unavailable; Deny authority if block available	Does nothing

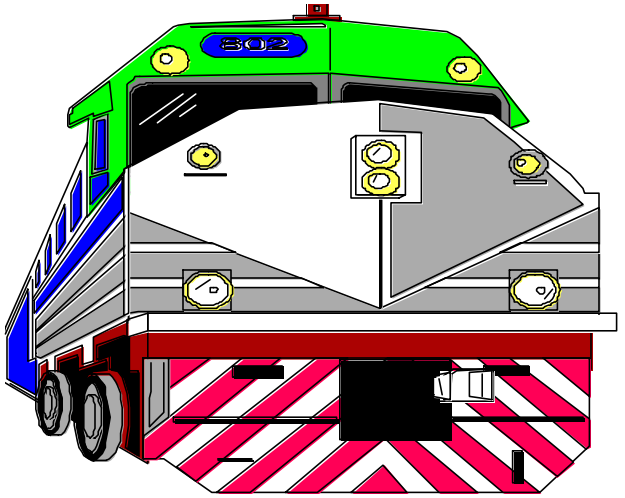
Knowledge Based Blackboard – Train Crew Response

Actual Stimulus	Train Crew Behavior		
	Correct Action (Compliance To Rule)	**Erroneous Action (Non-Compliance Rule)**	**Non-Response**
Radio communication from dispatcher: Grants authority to available appropriate block	GCOR ?: Move train at restricted speed through block and resume speed after rear of train has past restricted area	Increase speed within a range from current to maximum speed attainable by train	Does nothing
		Decrease speed within a range from zero to current	
		Apply full service braking	
		Apply emergency braking	

Knowledge Based Blackboard – Train Crew Response

Golden Stimulus	Train Crew Action					
	Proceed as directed by UPRR Special Instruction or GCOR	Proceed at Lower Speed than prescribed by UPRR Special Instruction or GCOR (Train movement not stopped)	Proceed at Higher Speed than prescribed by UPRR Special Instruction or GCOR	Apply Full Service Braking	Apply Emergency Braking	Does Nothing
Radio communication from dispatcher: Grants authority to available appropriate block	Safe Train Movement	Safe Train Movement	EPAD EPAD Incident/Accident Over speed work zone	Safe Train Movement	EPAD Incident/Accident	Safe Train Movement

A DAY IN THE SAFETY DEMANDS OF A CTC TRAIN SYSTEM



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MARCH 4, 2003
Philadelphia

Choice Model Knowledge-Based Blackboards

Dr. Donald E. Brown

Agenda

- Review of existing ASCAP Agent Model
- Definitions
- Choice Model Overview
- Example

Review of Existing Agent Model

- Agent model requires identification of intermediate behavioral states
  - Recognition
  - Interpretation
  - Coverage
  - Compliance
- Difficulties exist in obtaining probabilistic identification of behavioral states
- Choice process is limited
  - Does agent recognize need to act?
  - If the agent recognizes need to act, does the agent select the correct action (rule book compliant)?

ASCAP Agent Model Requirements

- Agent model must support various entities
  - Train Crew
  - Dispatcher
  - Roadway Worker
- Agent choices contingent upon physical environment
- Agent choices must allow for both correct (rule book compliant) actions & erroneous (rule book non-compliant) actions
- Knowledge based blackboard actions must be probabilistically assigned
  - Conditioned on physical environment
  - Conditioned on the present stimulus

Choice Model

- Used to identify an agents behavior
  - Assigns a range of probabilities to a set of possible choices (actions)

Environment

- State of physical surroundings at a specific instant that influences the decision that an agent takes
  - Train-centric snapshot
    - Train speed
    - Position
    - Weight
    - Length
    - Etc.

Environmental Attributes

- Measurable attributes associated with environment
- Unique set of attributes per agent
  - Rule book knowledge
  - Braking Safety
  - Operational Priority
  - L/V Ratio

Performance Shaping Factors (PSF)

- Agent attributes (scaled between 0 and 1) that influence agent choice
  - Experience
    - Function of the years of operation on a particular track or corridor
  - Training
    - Function of the amount of formal training.
  - Fatigue
    - Function of the length of time on duty and associated stress
  - Distraction
    - Function of concurrent agent activities

Stimulus

- An object or agent within the ASCAP simulated environment that demands an action from an agent.
  - Permanent speed sign
  - 3-Lamp Intermediate Signal
  - Flagging
- An agent must act when a stimulus coincides with their current environment

Utility Model

- Function that assigns a measurement identifying the level of satisfaction that an agent has for a given choice.
  - Level of satisfaction derived from an agent's preference for the set of available choices
  - Measurement is subjective with an expected level of uncertainty
  - Decision maker picks the alternative that provides the highest expected utility value

Choice Model Description

- Describes an agent's behavior when selecting an action
  - Characterizes the "choice'" process of agent
    - Agent attributes
    - Characteristics associated with each feasible action (choice)

Choice Model Benefits

- Assigns probabilities to actions considering multiple influences
  - Stimulus
  - Environment
  - Performance Shaping Factors

Choice Model Assumptions

- Independency between different environments
- Independency between alternative actions
- Weibull distribution for random utility component
  - McFadden (1973) Consumer behaviors
  - Ben-Akiva and Lerman (1985) Travel demand

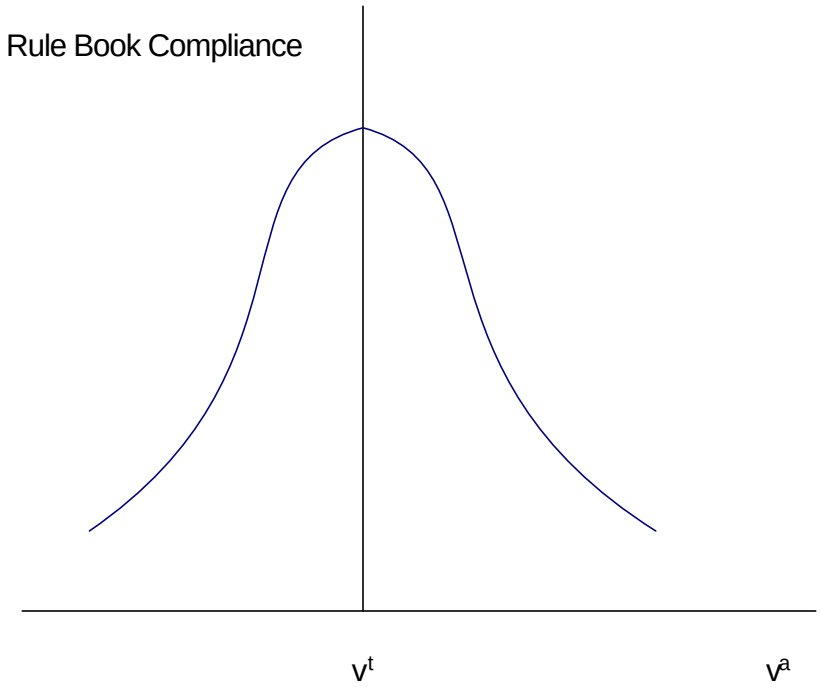
Defining the Initial Choice Model

- Model tuning and choice model calibrator
  - Calibrate the model with “agent in the loop” simulation
    - Environmental attributes
    - Performance Shaping Factors

Environmental Attributes – Rule Book Knowledge

- Measurement of compliance to the selected action with the railroad operational rule book

$$f_C(v^a - v^t) = \exp(-(v^a - v^t))$$



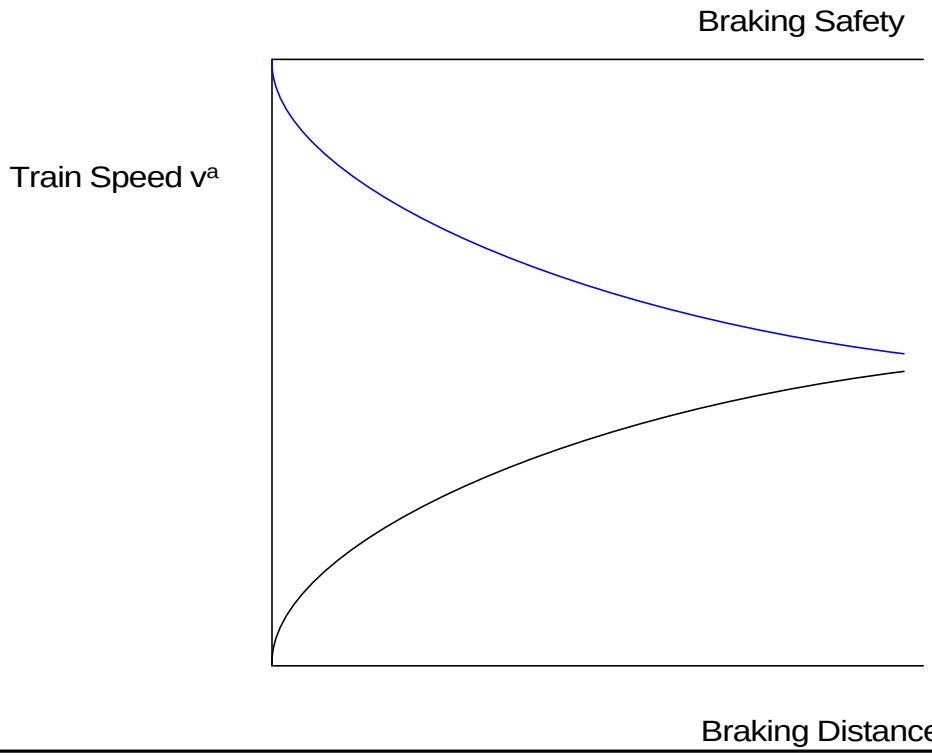
v^t : speed in selected action

v^a: Relative hours behind schedule (relative to actual start time)

Environmental Attributes – Braking Safety

- Measurement of braking safety

$$f_S(v^a) = 1 / f_{braking\,distance}(v^a)$$

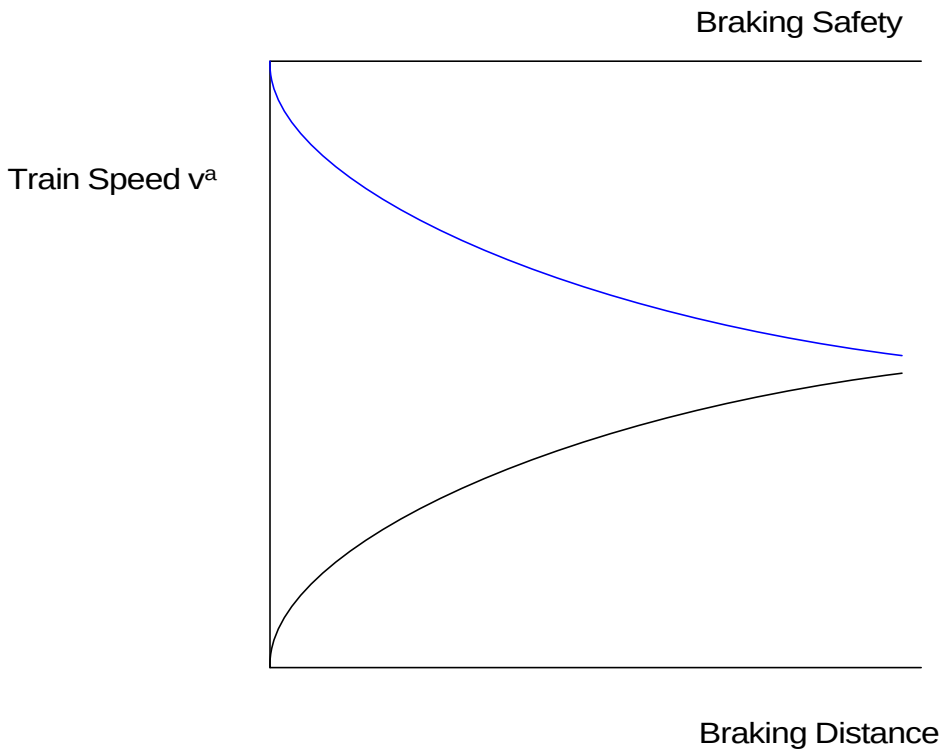


v^a: speed in the selected action

Environmental Attributes – Operational Priority

- Measurement of train crew stress relative to schedule

$$f_S(v^a) = 1 / f_{braking\ distance}(v^a)$$

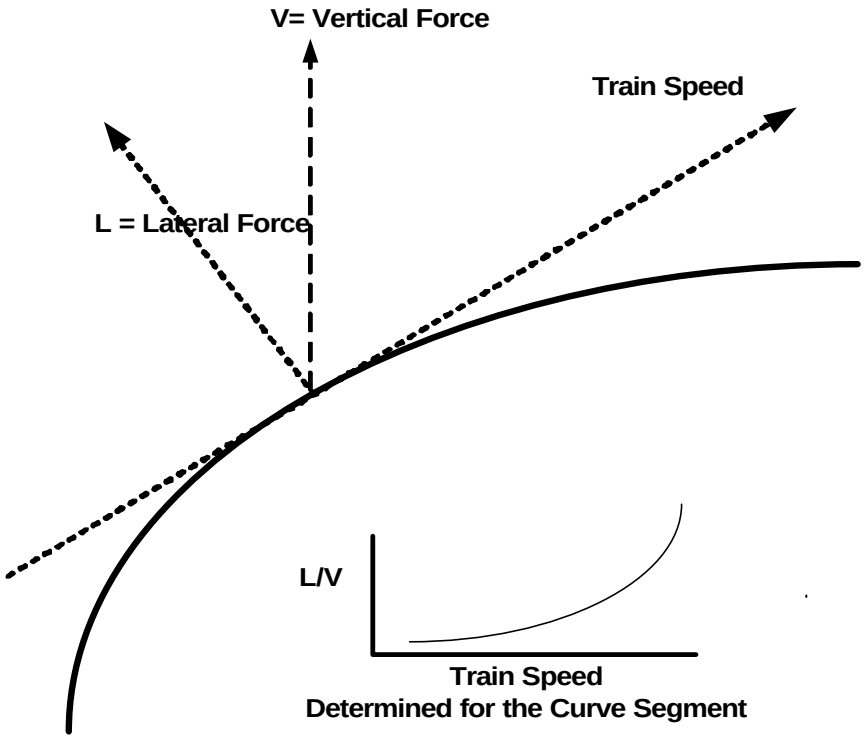


v^a: speed in the selected action

Environmental Attributes – L/V Ratio

- Measurement of derailment safety

$f_D(L, V)$=(Lateral Force)/(Vertical Force)



Utility Function of an Agent

$$U(action_i \mid stimulus, PSF_d) = \sum_j b_d^j X_{PSF_d}^j + \sum_k b_i^k X_{EA_i}^k + e_{id}$$

- X_{PSF_d}: Performance Shaping Factors of agent
- X_{EA_i}: Environmental attributes of action I
- β_d, β_i: Choice model parameters
- ε_{id}: Utility function random component
  - Independent & identically distributed

Derivation of Choice Model Probabilities

$$P(action_i \mid stimulus, PSF_d) = \frac{exp(\sum bX_{PSF_d} + \sum bX^{i}_{EA})}{\sum_j exp(\sum bX_{PSF_d} + \sum bX^{j}_{EA})}$$

Choice of Actions

- Correct action (rule book compliant)
  - Action 1: Change speed from 45 MPH to 30 MPH
- Erroneous action (rule book non-compliant)
  - Action 2: Change speed: 30 MPH< set speed < Maximum speed attainable by train
  - Action 3: Change speed: 0 MPH< set speed < 30 MPH
  - Action 4: Apply full service braking
  - Action 5: Apply emergency braking
- Non-response
  - Action 6: Keep train speed at 45 MPH

Environmental Attributes

	Rule Book Knowledge	Braking Safety	Operational Priority	L/V Ratio
Action1	1	0.6	0	0.6
Action2	0.18	0.0625	0	1.2
Action3	0.18	0.8	0	0.4
Action4	0.01	1	0	1.4
Action5	0.01	1	0	1.6
Action6	0.1	0.25	0	0.8

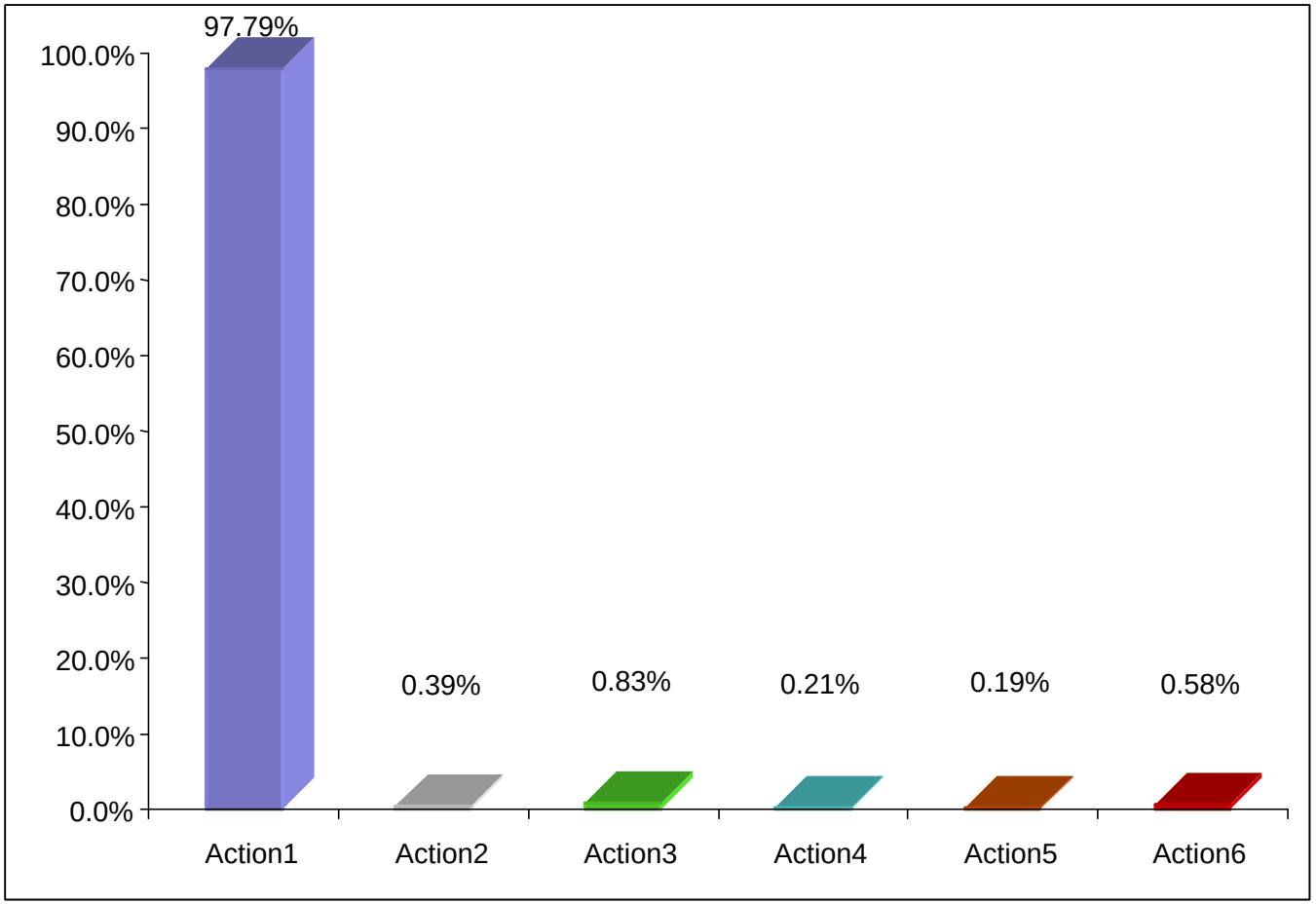
Performance Shaping Factors

	Experience	Training	Fatigue	Distraction
Train Crew	0.8	0.6	0.2	0.5

Choice Model Probabilities

	Probability
Action1	0.977
Action2	0.006
Action3	0.008
Action4	0.002
Action5	0.002
Action6	0.004

Choice Model Probabilities



Conclusions

- Choice model provides a new method for selecting knowledge based blackboard actions
- Performance Shaping Factors and environmental attributes influence agent decision making process
- Probabilities dynamically assessed

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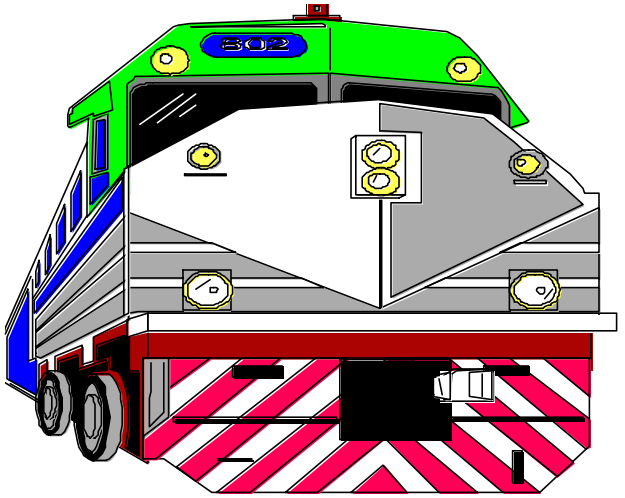

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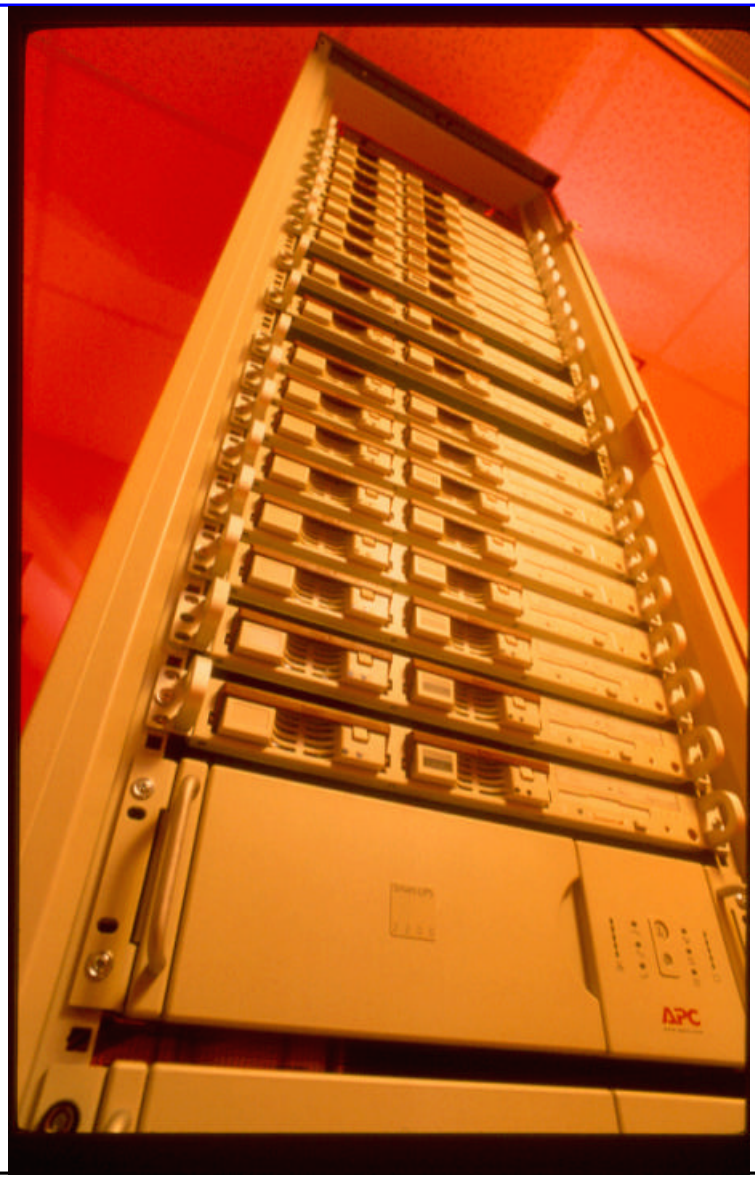
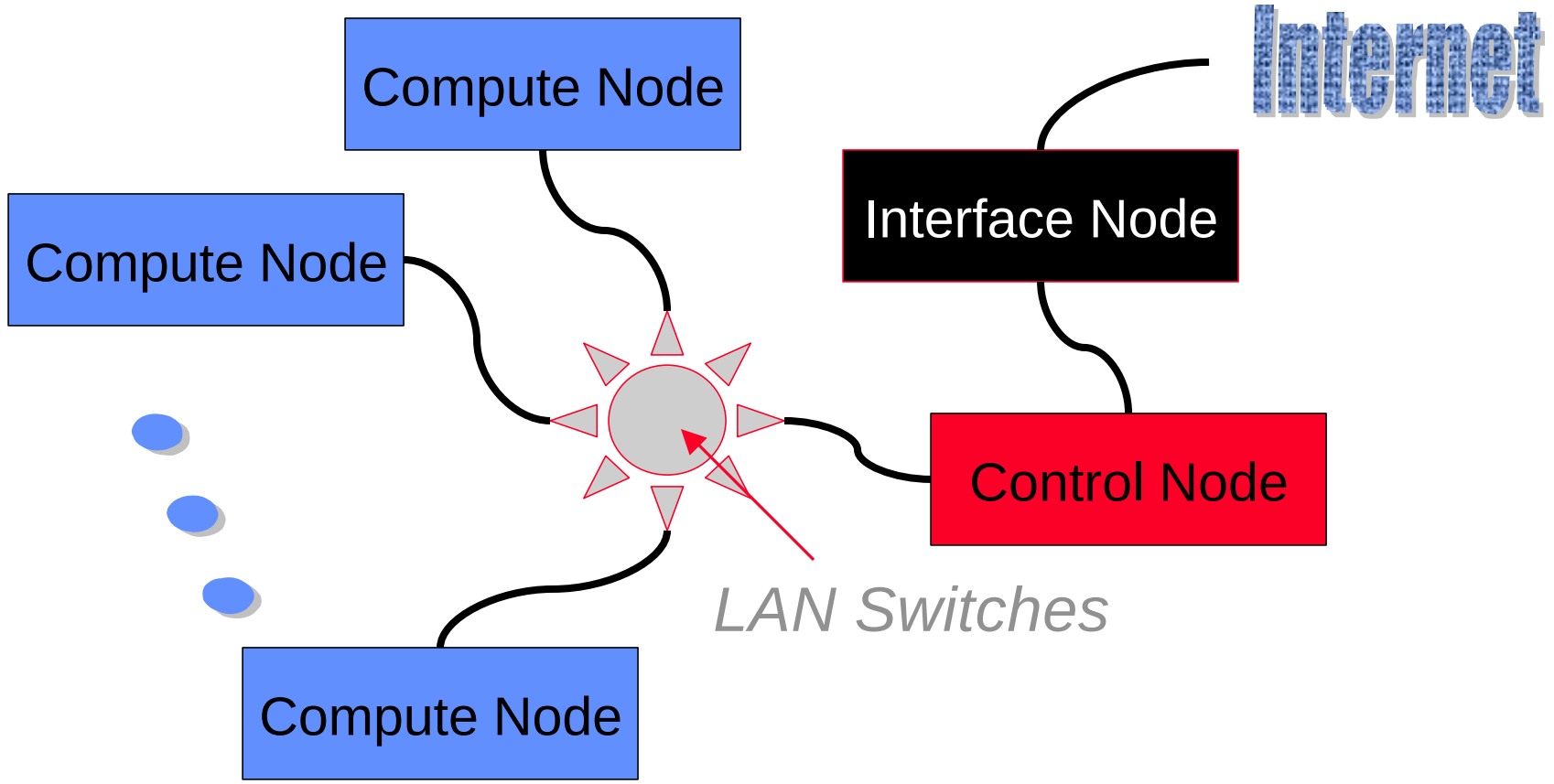
The Rail Analysis Cluster

Parallel Simulation

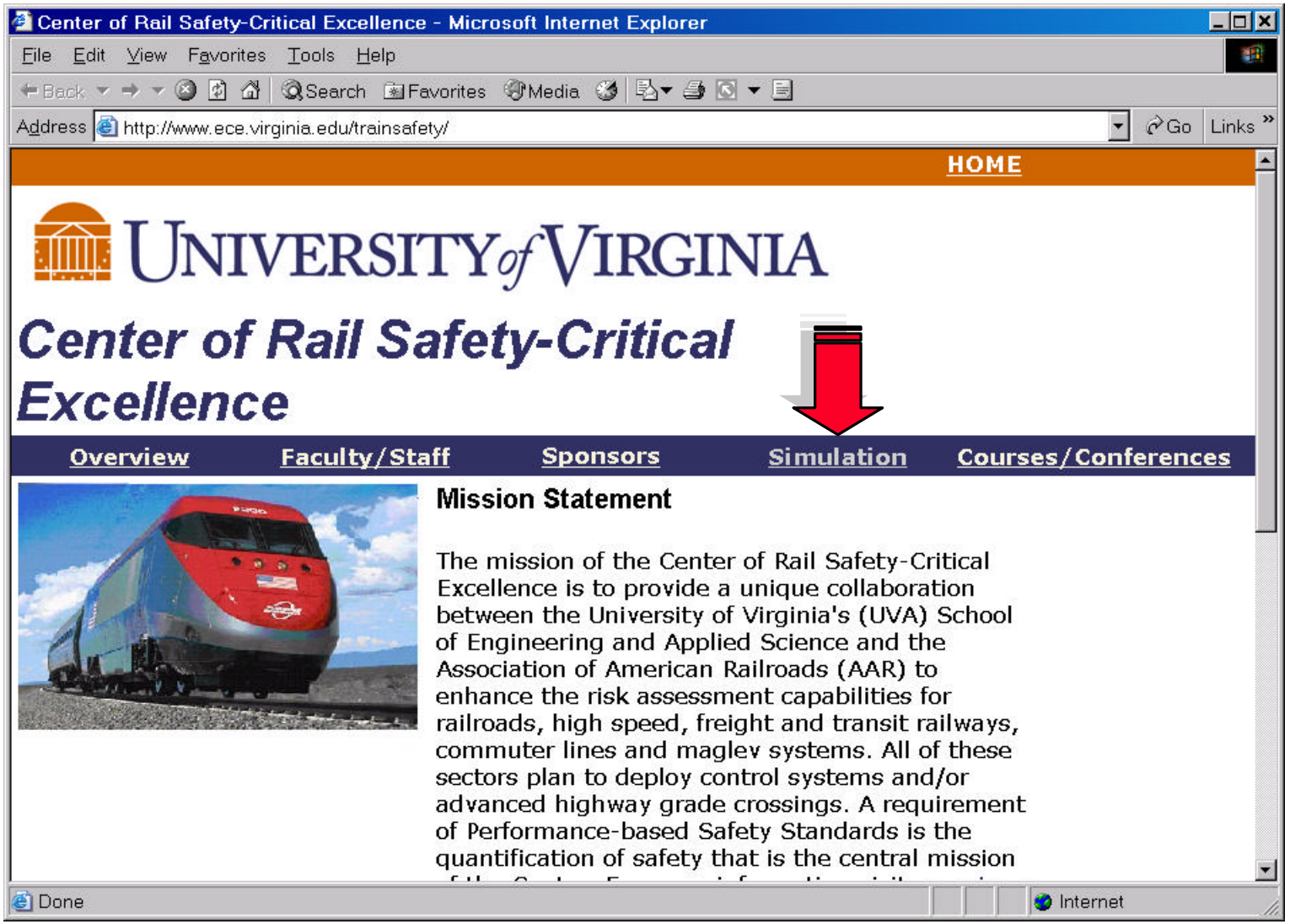
- The Rail Analysis Cluster (TRAC) currently contains 18 dual-processor computers.
- 16 of these computers are used as “compute nodes”
- 1 of these computers is used as the controller and coordination point for the 16 compute nodes
- 1 of these computers is used as an “interface node” running a secure web server



TRAC Topology



REAL WEB IMAGE



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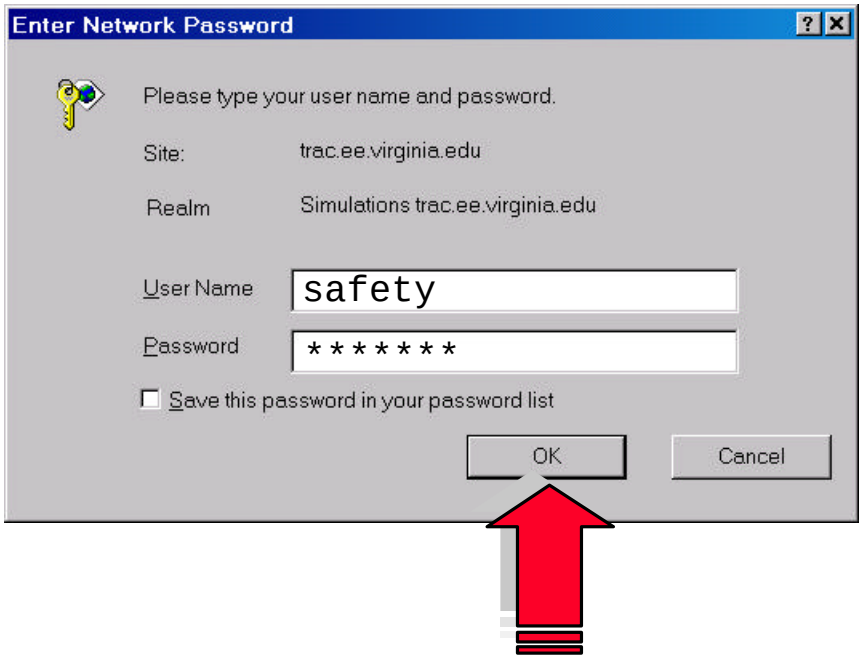

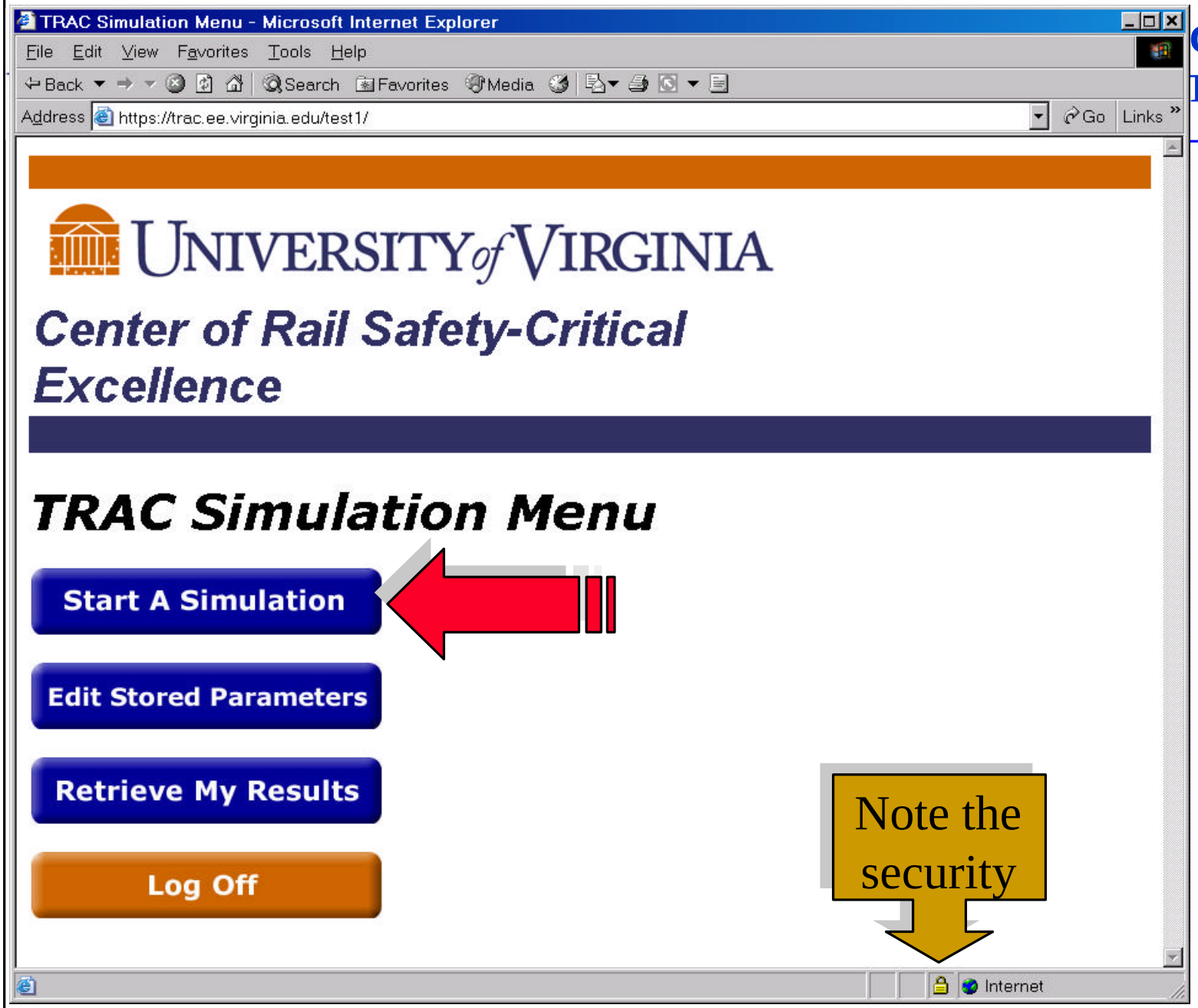

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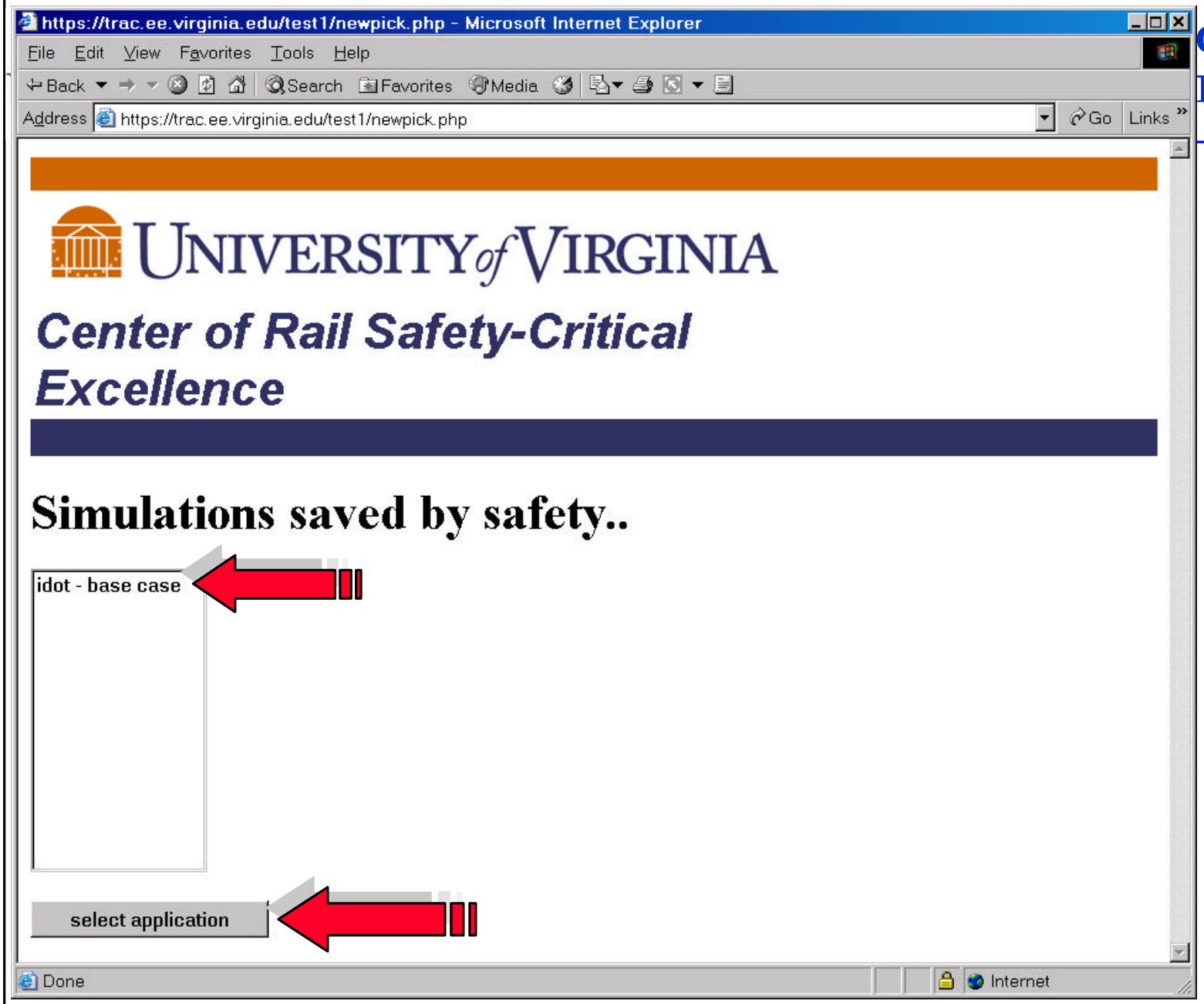
REAL WEB IMAGE



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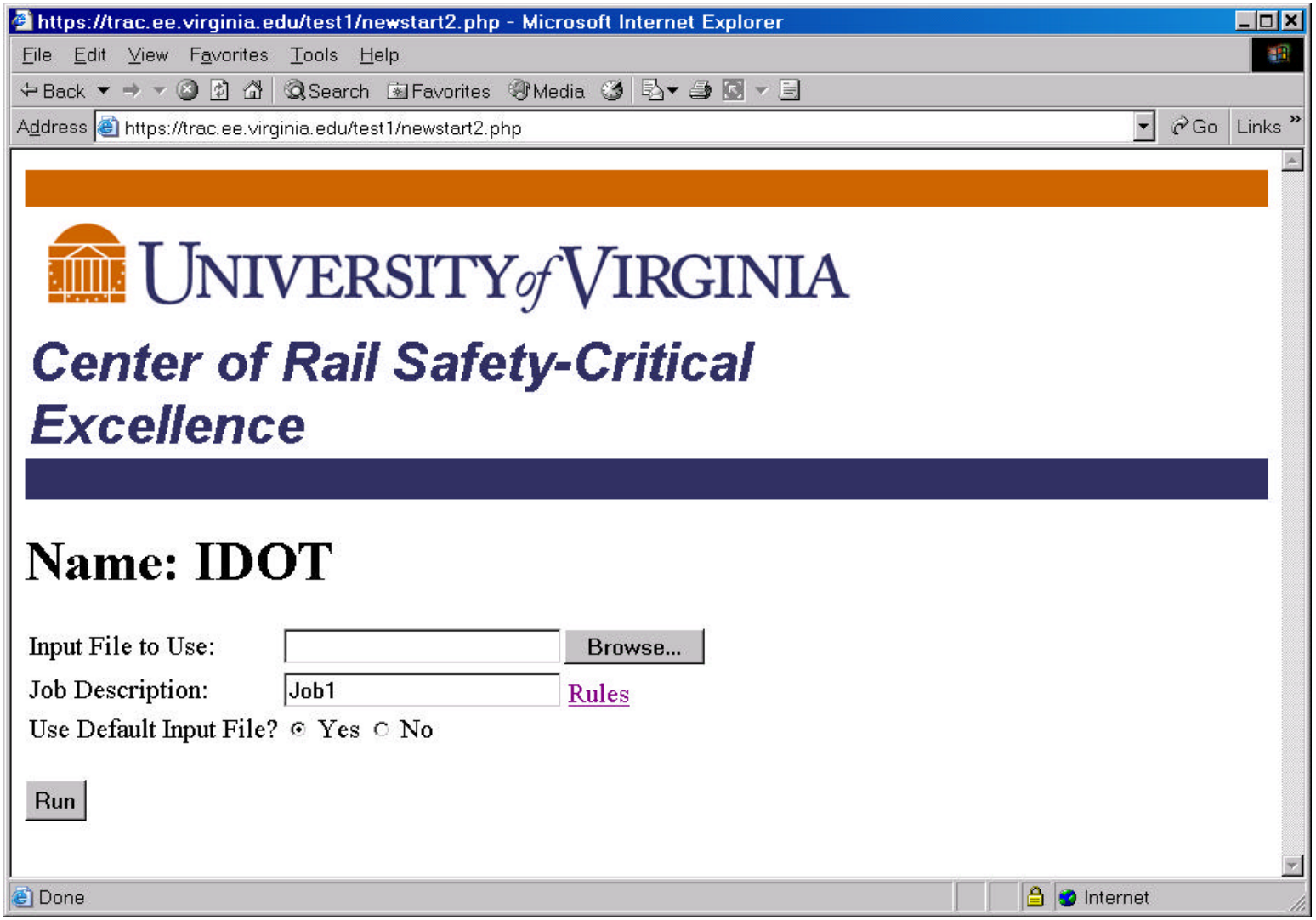

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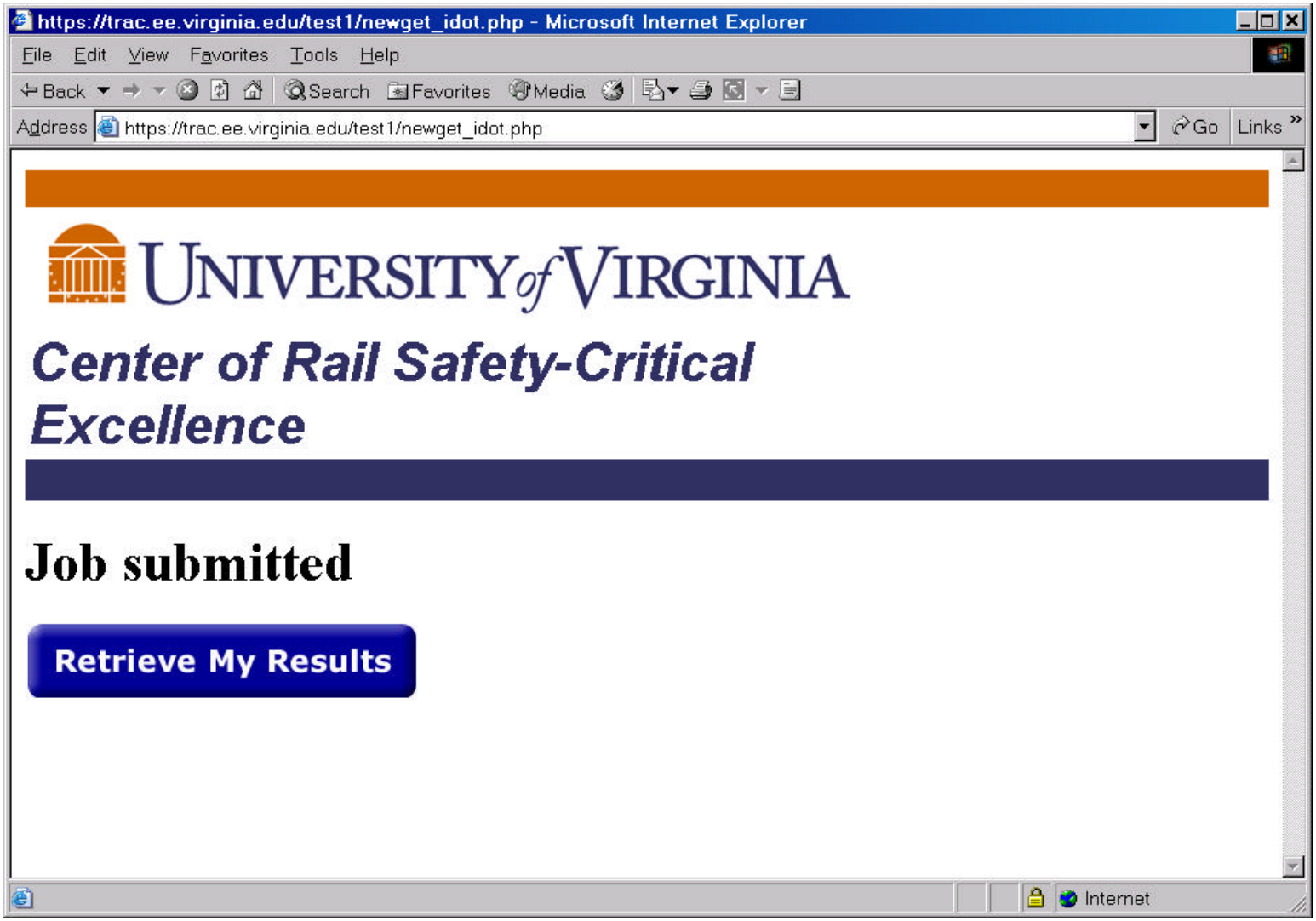

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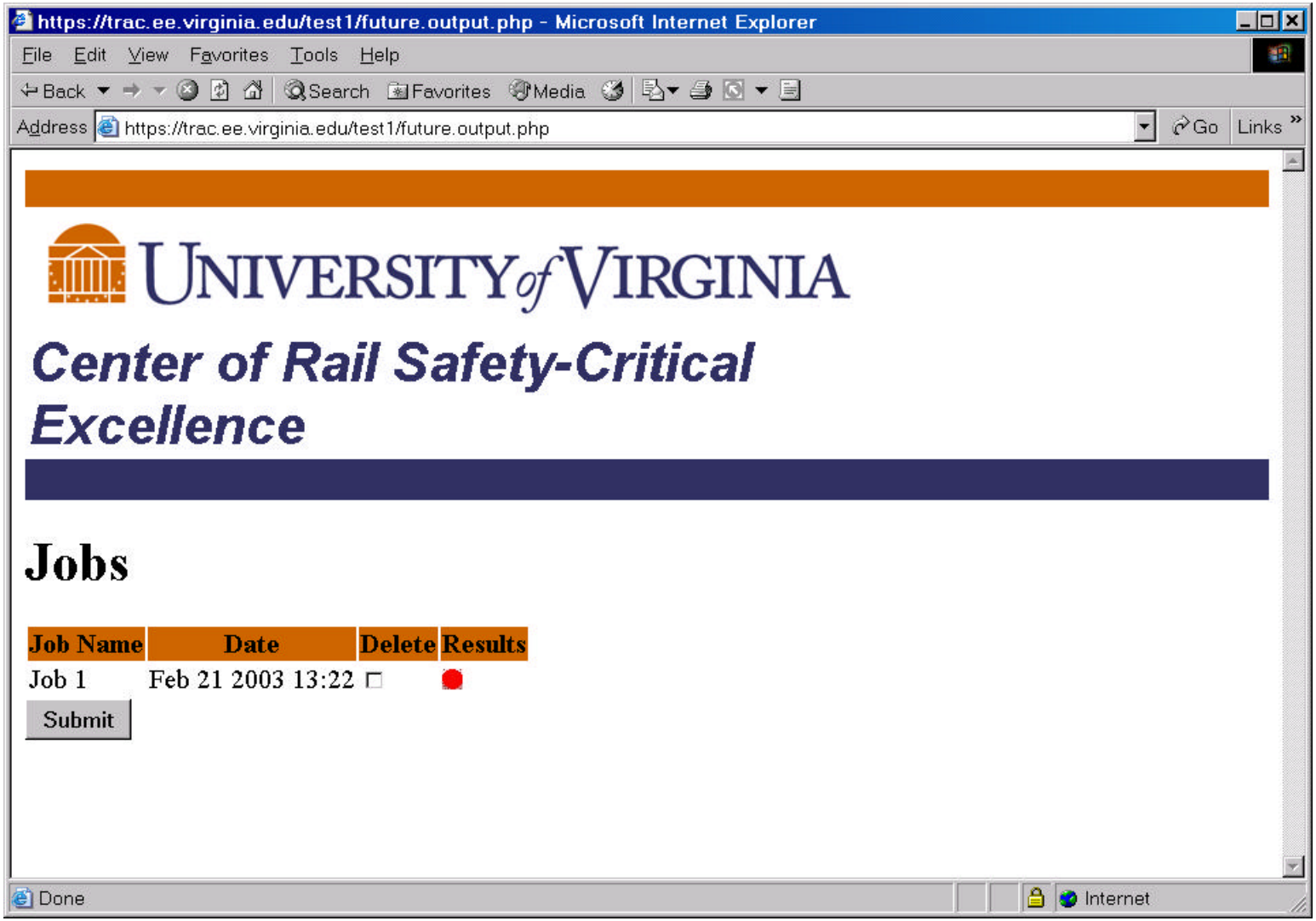
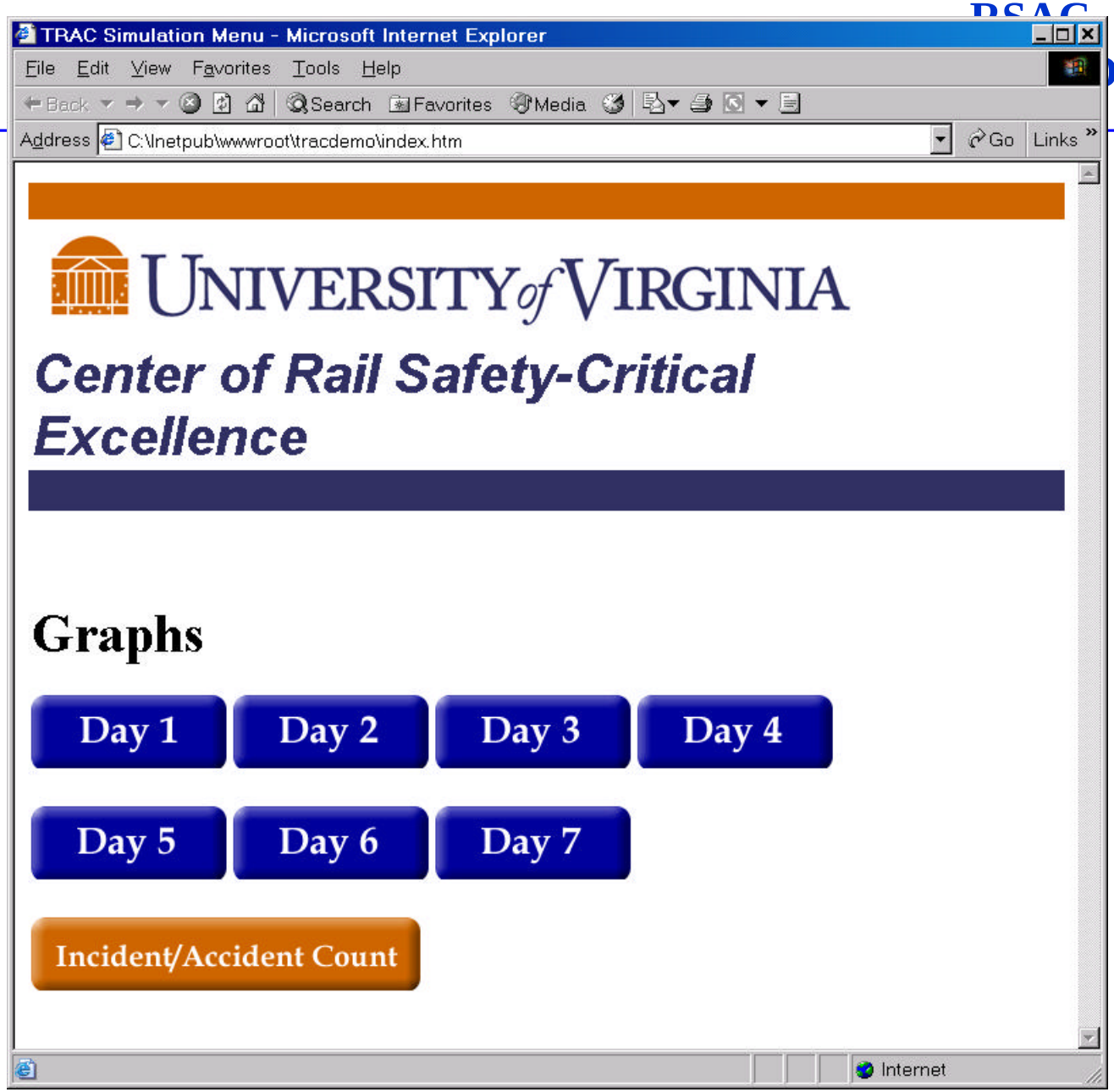


ILLUSTRATION



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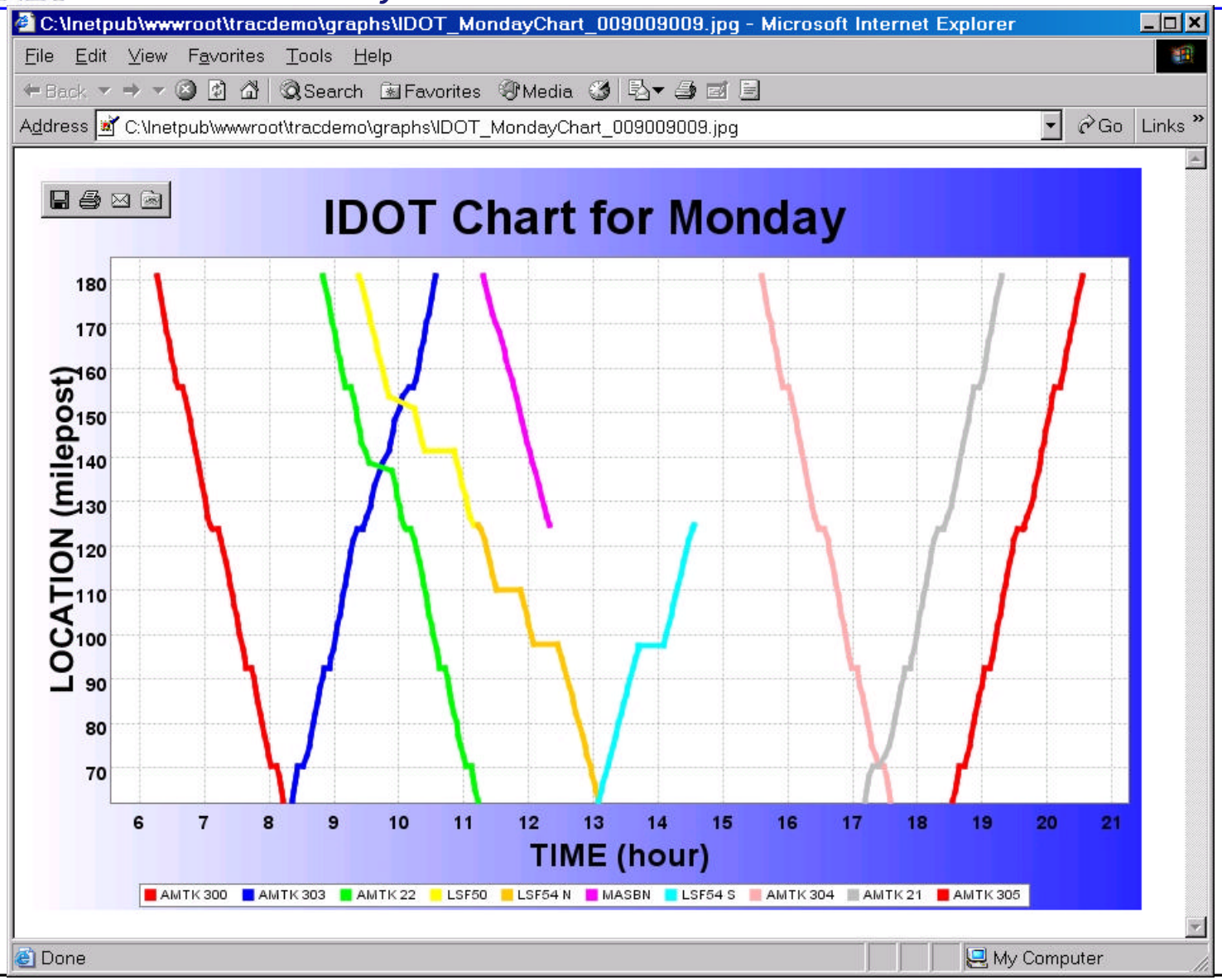

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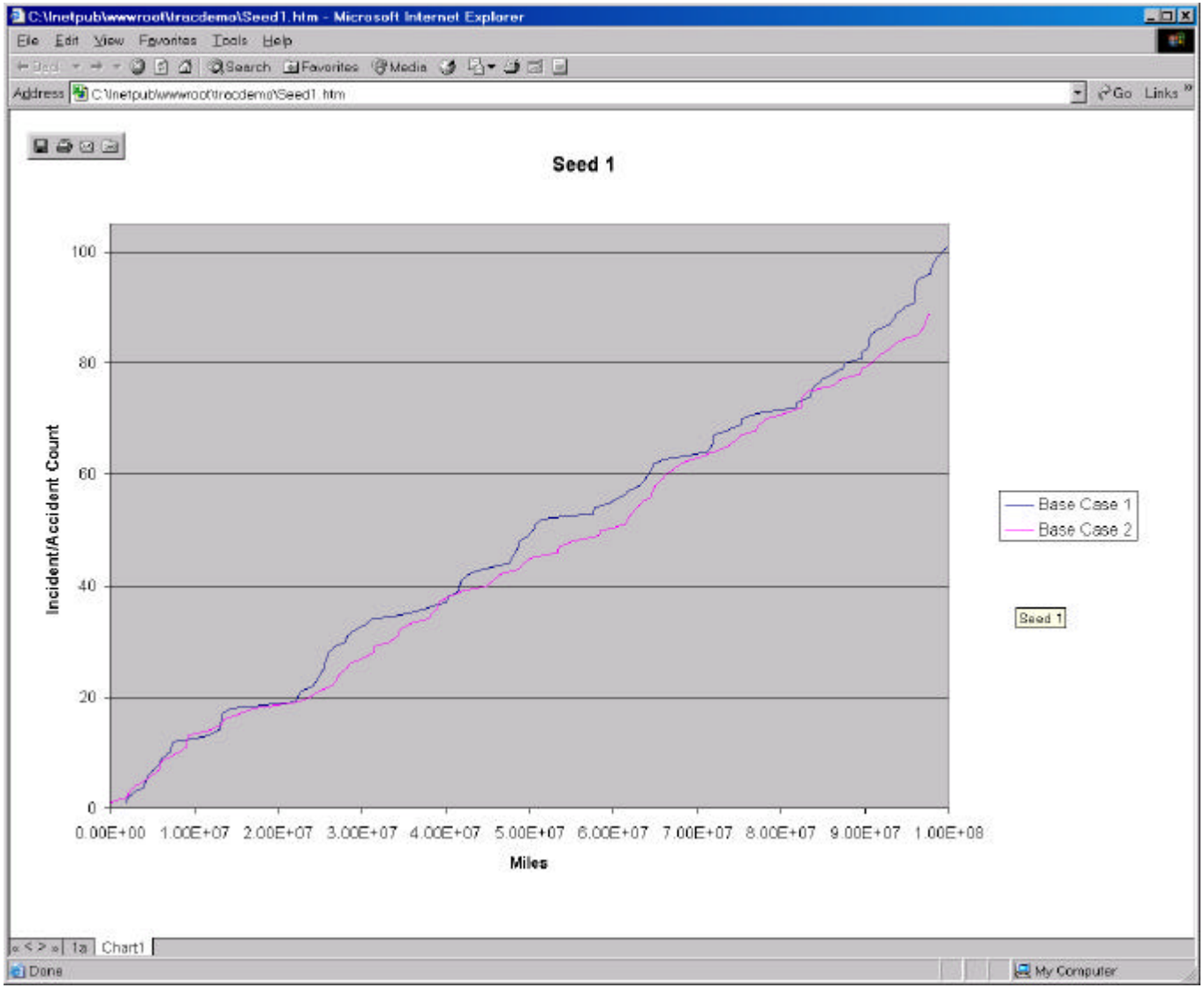
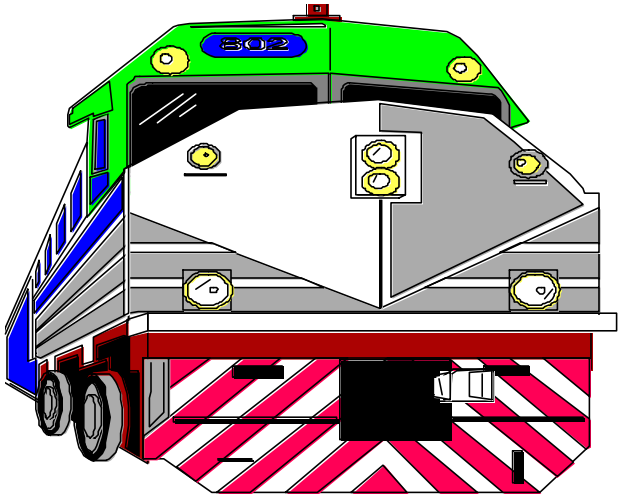


Group Comments and Discussion



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